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SPECIAL FEATURES

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EDITORIAL ANNOUNCEMENT

This issue of TRANSACTIONS, which is the first to be published in Cleveland since the establishing of national headquarters of the Society in that city, will reach its readers considerably behind its scheduled time. The delay has been necessitated through conditions arising in changing the place of publication and the volume of work resulting in adjusting schedules to the new conditions. Arrangements now have been completed for expeditious editing, printing, and mailing of the publication and it is believed that future delays will be eliminated. With hearty co-operation of all members of the society by sending in contributions and chapter news at the earliest moment possible, the editors will be able to place each issue of TRANSACTIONS in the hands of its readers promptly after the first of each month.

FEBRUARY ISSUE TO BE A DIRECTORY

By recent action of the Board of Directors of the Society, the February issue of TRANSACTIONS each year will be a membership directory. The next issue of the publication, therefore, will contain a complete alphabetical list of all members to date with information regarding their business connections, business addresses and mailing addresses. For convenience in reference, the members also will be classified according to geographical location. To make this directory as accurate and complete as possible, it is urged that all members who have not yet done so return to the National Secretary at once the information cards recently distributed.

RELATIVE THERMAL ECONOMY OF ELECTRIC AND FUEL-FIRED FURNACES

By E. F. Collins*

(A Paper Presented at Philadelphia Convention)

It is well known that the thermal efficiency of a fuel-fired furnace decreases rapidly with increasing working temperatures. This decrease is due primarily to the fact that the air required for combustion must be heated to the temperature of the furnace gases; the heat necessary to raise the air to this temperature usually being lost in the products of combustion as they escape. A secondary cause is the heat lost to the room from the walls of the furnace, which for convenience is called the radiation.

It is not possible to state with exactness the efficiency which may

*Consulting Engineer, Industrial Heating Devices, General Electric Co., Schenectady, N. Y.

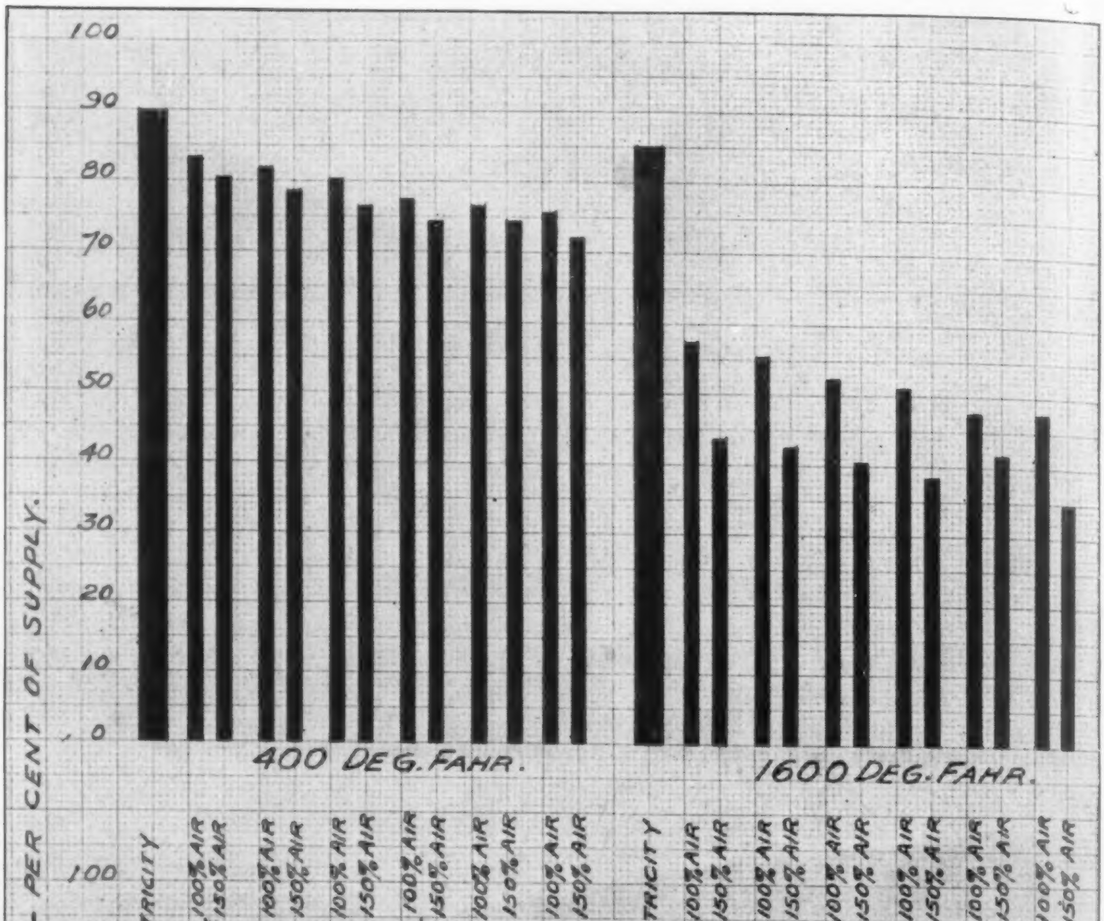

Fig. 1—Relative Thermal Efficiency of Electric and Fuel-Fired Furnaces at Various Temperatures

be realized in a furnace unless all the working conditions are known, as there are many factors which influence the amount of heat, its distribution and ultimate useful utilization. For instance, a part of the heat leaving the furnace may be recovered by preheating the fuel and incoming air, or by heating water or other materials for incidental uses; or the furnace may, in some cases, be constructed on the compensating or counter flow principle, when a considerable amount of heat may be returned to the incoming charge.

These possibilities obtain in general only in relatively large furnaces or installations, in which the plant and character of work admits of the utilization of the waste heat. The ordinary furnace and average plant operating conditions do not offer such opportunities for conservation of heat.

This paper deals with none of these compensating or regenerative schemes. The comparative thermal efficiency, therefore, is approximated by simple calculations for simple furnaces; since practically all of the theoretical heat represented by the temperature of the flue gases is lost and no approximations are necessary for completed auxiliaries.

Data showing the theoretical losses in flue gasses for various fuels at various temperatures has been submitted by others already, but it may be of interest to present this data in the form of tables and charts so as to make it available for ready reference in comparing the various fuels with electric heat, from the standpoint of thermal efficiency as well as the cost per heat unit when used for the same work and in furnaces of identical thermal loss from radiation.

The applications of electric heating are being very rapidly extended and, if the cost of electricity decreases as in the past, the point may soon be reached where the comparative cost even on a B.t.u. basis will not be unfavorable to electric heat. As a matter of fact, such a comparison at present prices is not unfavorable to electric heat at the higher temperatures as will be shown presently.

Table 1 has been compiled to show the heat losses and the cost per 100,000 B.t.u. actually utilized in useful work for various fuels including electricity, at temperatures of 500 degrees Fahr., 1600 degrees Fahr., 2300 degrees Fahr., and 2800 degrees Fahr., temperatures usually required for baking, heat treating, forging and melting respectively. The values of flue losses have been calculated for 100 per cent air; or the theoretical air required for perfect combustion, and also for 150 per cent air, or 50 per cent in excess of combustion requirements; which represents more nearly the average conditions.

Radiation losses of 15, 20, 30 and 40 per cent of the heat utilized respectively have been arbitrarily assumed for the four temperatures above mentioned and the same radiation loss has been assumed for all fuels, so that they are thus compared on the same basis; or it may be assumed that all the fuels are burned in the same furnace with perfect combustion and also with air in excess by 50 per cent.

Average calorific values of the fuels are stated and their costs per ton or per gallon, etc., are in round figures for easy calculations, so that any other costs per ton or per gallon may be applied readily.

It should be borne in mind that the heat available for useful work in the table, is the theoretical maximum for the conditions stated, perfect combustion being assumed in all cases. The values actually realized

in practice will represent a more or less lower efficiency than the tables and curves show. Note that in the case of electricity, which is perfectly converted into heat, that only a radiation loss occurs and escaping hot gases at furnace temperature do not exist as in fuel-fired furnaces.

Fig. 1 shows the heat available from Table 1 arranged in the form of charts and shows in a rather striking manner the relative efficiency of the various fuels at the four temperatures chosen. The rapid decrease of efficiency with rising temperature and increased air supply is at once apparent in the case of fuel-fired furnaces.

Fig. 2 shows the relative cost of fuels at various temperatures with 100 per cent air supply plotted as curves, and Fig. 3 shows the corresponding cost for 150 per cent air supply, the values having been plotted from the last column of Table 1. Fig. 1 shows the high ratio of heat units utilized to heat units supplied by electricity as compared with combustible fuels, while Fig. 2 and Fig. 3 show its comparative cost per 100,000 B.t.u.

For fuel cost other than those chosen, curves may be plotted by multiplying the values in the last column of the table by the ratio to actual fuel cost. For instance, for oil at 14 cents per gallon, or electricity at 1.25 cents per kilowatt hour, multiplying the values in the last column of the table by 1.4 or 1.25 and plot a new curve.

The foregoing is of course on a strictly B.t.u. basis, without regard to the expense of handling or storing fuels, or to the cost or repairs, convenience of manipulations, etc.

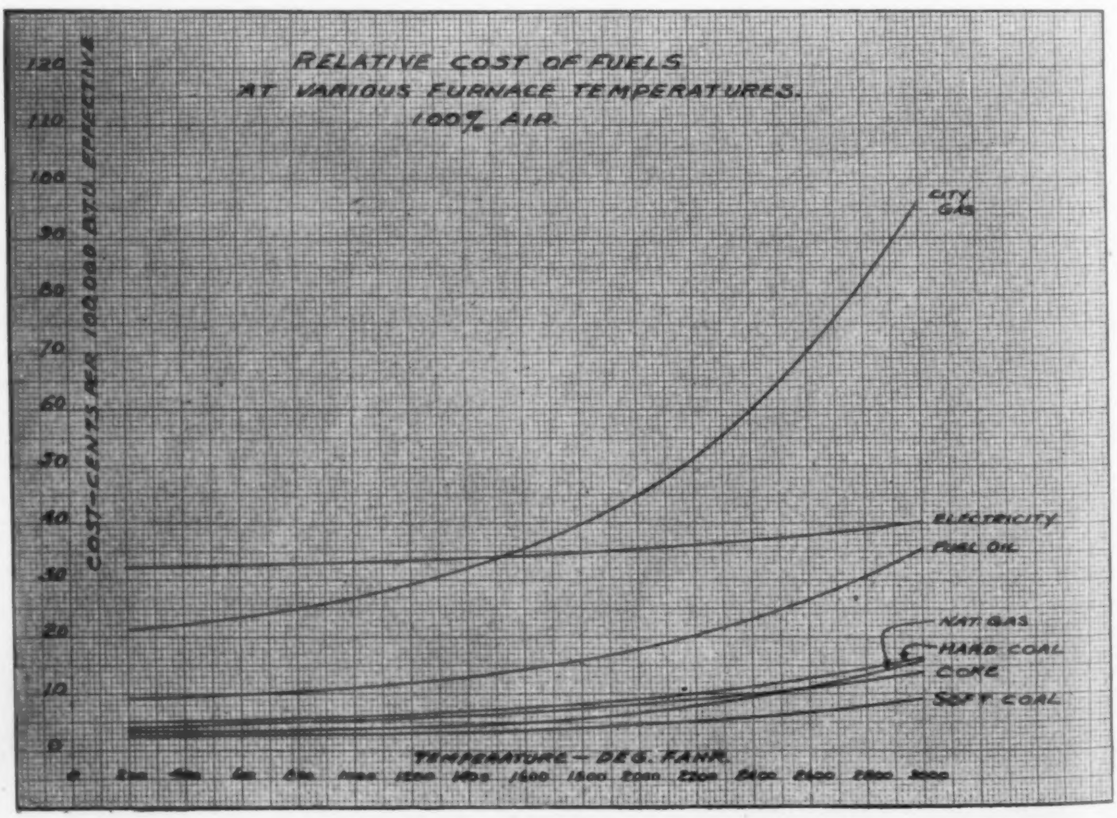

Fig. 2

It has been demonstrated that even at a higher cost per heat unit, electric heat in many cases, is actually cheaper and at the same time offers an opportunity to increase output and improve the quality of the product, so that the net results show a very considerable reduction in the manufacturing cost. Indeed, the rapid increase in the use of electric heating equipment is in itself proof that the advantage accompanying the use of electric heat in many cases outweighs any additional cost of the electric heat unit which may exist.

Coal and coke are relatively difficult and expensive to store and fire, and natural gas is restricted to comparatively local areas. Further, the supply available at present is such that it is not entirely dependable. Artificial gas is rather expensive and it is not always available in quantities so that fuel oil has naturally become the chief source of heat in many of our industries, due to the convenience with which it can be stored, handled and distributed, its concentrated thermal value and its past relatively less cost and abundant supply.

Oil, therefore, has been a popular fuel and its use has become widespread. However, the very considerable increase in its cost recently and its apparent scarcity has brought about a condition which is very trying to industrial managers, many of whom have become interested in electric heating as a solution of the fuel problem as well as many incidental problems.

It is proposed, therefore, to show very briefly some of the later applications in which electric heating has met with marked success and to indicate some of its possibilities.

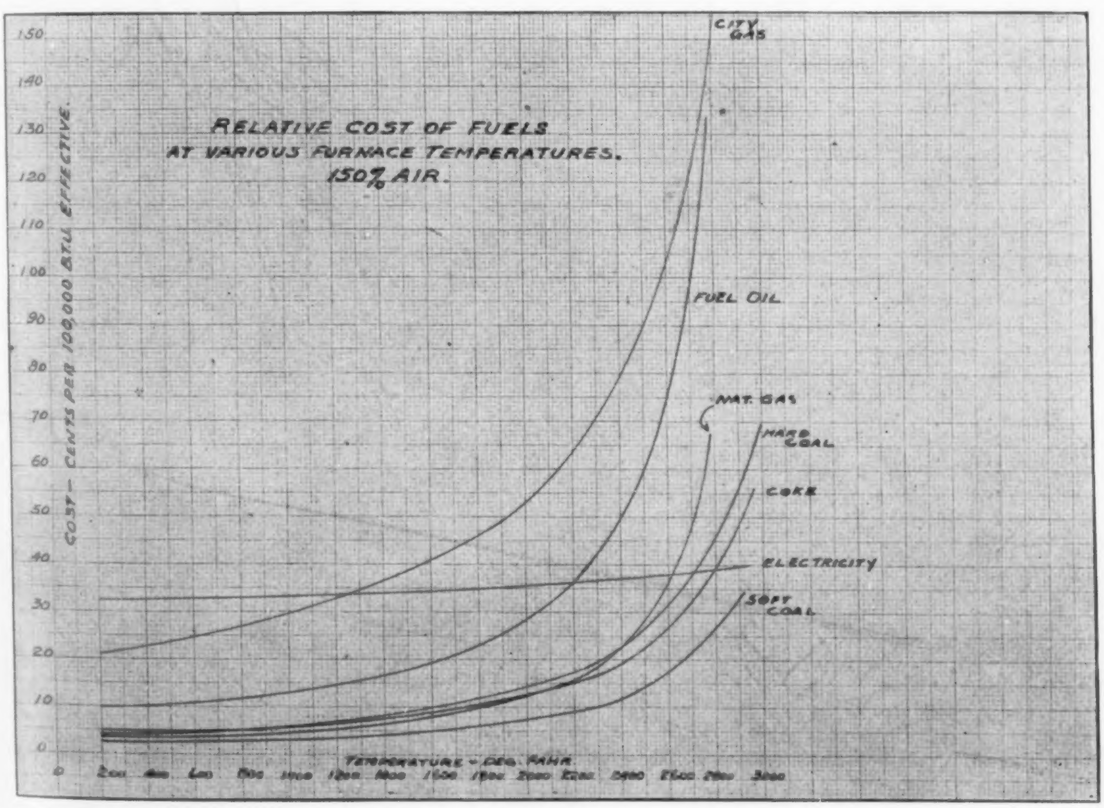

Fig. 3

The advantages of electric heating are, in general, well recognized, but the impression seems to prevail that the cost of operation is excessive. This is true in certain instances, for example, in cases where the nature of the process permits the recovery of waste heat from the flue gases.

Electric heating has been applied successfully over the entire range of temperatures, from low temperature ovens for drying and baking to high temperature furnaces for melting and refining, thus equipments are available for many applications.

TABLE I

Fuel Heat Losses and Cost per 100,000 B. T. U's.

Source of heat	Per cent of air for perfect combustion air at 70 deg. F.	Calorific value of fuel or power B.T.U.	Temperature of furnace	Rate paid for fuel or power	Cost per 100,000 B.T.U.	Losses		Total B.T.U. required for 100,000 B.T.U. effective	Thermal efficiency of furnace	Cost per 100,000 B.T.U. effective
						Per cent of available B.T.U. lost in flue gases	Assumed radiation B.T.U.			
Coke	100	13,000 per lb.	400 deg. F.	$10.00 per ton	$0.0385	7.5	15000	124000	80.6	$0.0477
"	150	" "	" "	" "	"	10.5	15000	128500	77.8	0.0493
"	100	" "	1600 deg. F.	" "	"	32.5	20000	178000	56.2	0.0685
"	150	" "	" "	" "	"	48.5	20000	233000	43.0	0.0898
"	100	" "	2300 deg. F.	" "	"	47.5	30000	248000	40.3	0.0955
"	150	" "	" "	" "	"	71.0	30000	448000	22.3	0.1730
"	100	" "	2800 deg. F.	" "	"	57.5	40000	330000	30.3	0.1270
"	150	" "	" "	" "	"	87.0	40000	1,011,000	9.3	0.415
Electricity	...	3415 per K.W.H.	400 deg. F.	1c per K.W.H.	$0.293	0	15000	115000	87.0	$0.337
"	...	" "	1600 deg. F.	" "	"	0	20000	120000	83.5	0.352
"	...	" "	2300 deg. F.	" "	"	0	30000	130000	77.0	0.380
"	...	" "	2800 deg. F.	" "	"	0	40000	140000	71.5	0.410
City gas	100	590 per cu. ft.	400 deg. F.	$1.00 per M	$0.17	15.0	15000	135000	74	$0.230
"	150	" "	" "	" "	"	17.5	15000	139000	72	0.236
"	100	" "	1600 deg. F.	" "	"	44.0	20000	214000	46.7	0.364
"	150	" "	" "	" "	"	51.0	20000	245000	40.8	0.416
"	100	" "	2300 deg. F.	" "	"	60	30000	325000	30.8	0.552
"	150	" "	" "	" "	"	70	30000	433000	23.1	0.736
"	100	" "	2800 deg. F.	" "	"	72.5	40000	509000	19.7	0.865
"	150	" "	" "	" "	"	85	40000	933000	10.7	1.585
Fuel oil	100	19,000 per lb.	400 deg. F.	10c per gal.	$0.0748	14	15000	134000	74.6	$0.100
"	150	" "	" "	" "	"	17.5	15000	139000	72.0	0.104
"	100	" "	1600 deg. F.	" "	"	40	20000	200000	50.0	0.150
"	150	" "	" "	" "	"	55	20000	267000	37.5	0.200
"	100	" "	2300 deg. F.	" "	"	56	30000	296000	33.8	0.222
"	150	" "	" "	" "	"	77.5	30000	577000	17.3	0.432
"	100	" "	2800 deg. F.	" "	"	67.5	40000	430000	23.3	0.322
"	150	" "	" "	" "	"	94	40000	2,330,000	4.3	1.745
Anthracite coal	100	12,000 per lb.	400 deg. F.	$10.00 per ton	$0.0425	9.0	15000	126500	79	$0.0548
"	150	" "	" "	" "	"	12.5	15000	131500	76	0.0570
"	100	" "	1600 deg. F.	" "	"	35 0	20000	185000	54	0.0805
"	150	" "	" "	" "	"	50.0	20000	240000	41.7	0.1020
"	100	" "	2300 deg. F.	" "	"	50	30000	260000	38.5	0.1105
"	150	" "	" "	" "	"	72.5	30000	473000	21.1	0 2010
"	100	" "	2800 deg. F.	" "	"	60	40000	350000	28.6	0.1490
"	150	" "	" "	" "	"	87.5	40000	1,120,000	8.93	0.476
Bituminous coal	100	12,550 per lb.	400 deg. F.	$5.00 per ton	$0.020	11	15000	129000	77.5	$0.0258
"	150	" "	" "	" "	"	15	15000	135000	74.0	0 0270
"	100	" "	1600 deg. F.	" "	"	38.5	20000	195000	51.3	0.0390
"	150	" "	" "	" "	"	52.5	20000	253000	39.5	0.0506
"	100	" "	2300 deg. F.	" "	"	55	30000	289000	31 6	0.0578
"	150	" "	" "	" "	"	75	30000	520000	19.2	0 1040
"	100	" "	2800 deg. F.	" "	"	65	40000	400000	25.0	0.0880
"	150	" "	" "	" "	"	90	40000	1,400,000	7.15	0.2800
Natural gas	100	1100 per cu. ft.	400 deg. F.	30c per M	$0.0273	16.2	15000	137000	73.0	$0.0374
"	150	" "	" "	" "	"	20	15000	144000	69.5	0.0393
"	100	" "	1600 deg. F.	" "	"	44	20000	214000	46.7	0.0585
"	150	" "	" "	" "	"	59	20000	292000	34.2	0 0797
"	100	" "	2300 deg. F.	" "	"	60	30000	325000	30.8	0.0886
"	150	" "	" "	" "	"	81	30000	685000	14.6	0.1870
"	100	" "	2800 deg. F.	" "	"	72.5	40000	510000	19.6	0.1390
"	150	" "	" "	" "	"	97.5	40000	5,600,000	1.8	1.530

Electric ovens for baking enamel are so widely used and their advantages so well known that it is hardly necessary to do more than refer to them here. Their extensive use for enameling automobile bodies and parts, in other words, where a superior finish is required, is sufficient argument as to their economy.

Ovens for baking foundry cores are also yielding excellent results from the standpoint of efficiency and net cost, particularly for small cores, in which breakage and loss from uneven baking usually is a very considerable item. The uniform distribution and automatic

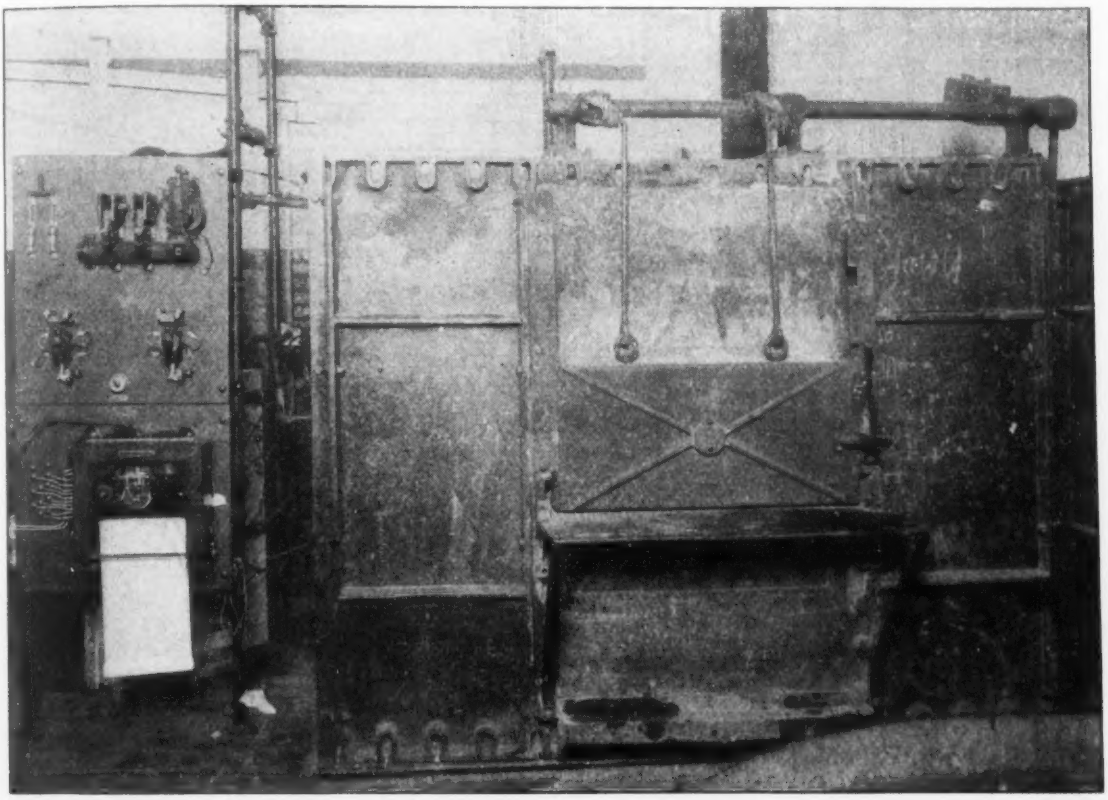

Fig. 4—Electric Resistance Furnace with Panel and Instrument for Automatic Temperature Control

temperature control possible with electric heat considerably shortens the time required for baking and produces perfectly baked cores, thus the losses are reduced and rejects seldom occur.

Several installations have been made in wire mills, all of which have showed a substantial saving. The following data is typical, and shows the actual cost of baking steel wire to remove grease and drying it after pickling. These are operations which require no refinement, since it would not be expected that electric heat would have any advantages whatever if judged on a B.t.u. basis alone.

The installation referred to has both electric ovens and coke-fired ovens of the same dimensions. Electricity is by far the most expensive fuel on a B.t.u. basis at drying and baking temperatures as shown in Figs. 2 and 3, while coke is among the cheapest possible fuels. Therefore, a direct comparison in the same plant is interesting as follows:

Tests of Electric and Coke-Fired Wire Baking Ovens

Baking at 525 Degrees Fahr., Cycle 10-12 Hours

Electric	Actual test 10 per cent output	Test results reduced to 100 per cent output
Cost of power per net ton of steel	$5.087	$ 1.19
Annual charges per net ton	7.839	0.727
Total cost per net ton	$12.926	$ 1.917
Coke		
Cost of coke per net ton of steel	0.921	.171
Annual charges per net ton	21.368	1.983
Total cost per net ton	$22.289	$ 2.154

Baking at 350 Degrees Fahr., Cycle 1-10 Hours

Electric	Actual test 35 per cent output	Test results reduced to 100 per cent output
Cost of power per net ton of steel	$0.787	$ 0.515
Annual charges per net ton	0.648	0.187
Total cost per net ton	$1.436	$ .702
Coke		
Cost of coke per net ton of steel	$0.253	$ 0.146
Annual charges per net ton	1.766	0.510
Total cost per net ton	$2.019	$ .656

The normal output of these ovens is considerably less than the maximum capacity, so that "normal" results, or results from observation are given, as well as results which might be expected if they were operated at full capacity.

These figures show, as might reasonably be expected, that the cost of fuel in the coke-fired ovens is practically negligible in comparison with the cost of handling, repairs and other charges. In the electric ovens the cost of power is the principle item.

Perhaps a more familiar example is an ordinary hearth-type furnace as used for hardening tools, dies, cutters, etc. Tests were run on an oil furnace and on an electric furnace, both having about the same hearth area and doing the same kind of work at the same temperatures.

Tests of Electric and Oil-Fired Hardening Furnaces

	Electric	Oil-Fired
Dimensions heating chamber	30 x 36 x 42 inches high	48 x 24 x 20 inches high
Length of test (heating steel)	107 Hrs.	31.75 hrs.
Average temperature held	1450 deg. F.	1400 deg. F.
Amount of steel heated	1451 lbs.	2670 lbs.
Amount of steel heated per hr.	13.6 lbs., 84 lbs. (Calc)	84 lbs.
Fuel and power to hold at 1400 deg. F.	8.04 K. W. H. per ht.	1.65 ga. per hr.
Fuel and power while heating steel	8.96 K. W. H. 12.36 K.W.H. (Calc)	1.9 gal. per hr.
Fuel and power rate	1.25c per K. W. H.	14c per gal.
Fuel and power per lb. of steel	0.65 K. W. H. 0.147 K.W.H. (Calc)	0.022 gal.
Cost per hour to hold 1400 deg. C.	10 c	23.1c
Cost fuel and Power per lb. steel	0.008 0.0018 (Calc)	0.0030

With both furnace tests corrected to the same output of 84 pounds of steel per hour at 1450 degrees Fahr., the ratio of cost of oil burned to the electric power required is 0.0030 divided by 0.0018 or about 1.7.

In other words, these tests show cost of operating with oil to be 70 per cent greater than heating by electric power.

It may be said that this electric furnace is provided with automatic temperature control and a time switch which throws off the power at the end of the working day and throws it on in the early morning so that the furnace is always ready for use. This furnace and control equipment are shown in Fig. 4.

It is obvious from the above data that the fuel used in actually heating steel is almost negligible in either furnace, which is of course well known. The data shows that the cost of maintaining temperature in the oil furnace is more than double the cost for the electric furnace.

This may perhaps be surprising to many who base their calculations entirely on the relative cost of B.t.u's. It would be still more surprising if the cost of repairs and fixed charges could be included in the comparison. This cost for the electric furnace is practically zero. The figures for this size of oil furnace are not available to the writer, although they are probably available from other sources.

The fact which it is desired to emphasize is that the oil furnace referred to, is typical of thousands in regular use on heat treating, which could be heated by electricity for less than half the fuel cost alone, to say nothing of the saving in repairs. This represents a considerable loss to the individual manufacturer, but in the aggregate it is an enormous economic waste.

An interior view of this type of electric furnace is shown in Fig. 5 which, however, is a somewhat larger furnace than shown in Fig. 4.

A large number of these furnaces are in daily operation for such work as annealing, hardening and carbonizing for which they are particularly well suited. The furnace shown in Fig. 5 is one of a pair which are used for carbonizing. All of these furnaces are equipped with automatic temperature control.

The furnaces referred to are of the metallic resistor type and are suitable for operation to 1000 degrees Cent. (1800 degrees Fahr.). For higher temperatures, such as are required for forging and melting, a form of carbon furnace is available.

There are a number of electric brass melting furnaces in operation, most of which have been built in the last few years, in fact, furnaces being installed today for melting brass are largely electric furnaces. This is an index of the rate at which electric heating is being adopted, and it seems safe to predict that it will supplant fuel oil to a considerable extent for such purposes within the next decade.

Enormous quantities of oil now are used in the operations of annealing, heat treating and forging. The electric furnaces previously referred to are ideal for this annealing and heat treating, and a resistance furnace now is being built for forging steel on a commercial scale. This furnace, which is designed on thoroughly tested principles, appears to be very promising.

It is unnecessary to dwell upon the many inherent advantages of electric furnaces, such as easy and positive temperature control, absence of noise, products of combustion and excessive heat duplication of results, etc., as these features are well known. It is desired, however, to emphasize the fact that, contrary to the general impression in the past, the cost of electric operation is not excessive, but in many

cases is no greater and often is considerably less than with fuel-fired furnaces.

The era of electric heating has begun, and it may well be expected that electricity will ultimately be used as widely for industrial heat as it is for industrial power at the present time.

In conclusion, the real object of this paper is to call attention to the fact that fuel cost does not determine heating cost or overall manufacturing costs. It is essential that heating propositions receive careful study and all conditions associated with the process be considered with each type of fuel furnace and the electric furnace. Then and then only should it be decided whether heating should be done with electricity or with some kind of fuel.

The writer is in accord with the observations of a prominent furnace engineer and builder which were as follows:

"To heat with coal, cook with gas, and light with electricity is considered good practice in a dwelling, yet some people think one type of furnace and one fuel is good enough for the more complicated heating operations in a factory.

"There are furnaces and fuels just as there are shops and shops, but the furnaces and fuel you require should be selected to suit your needs for the same reason that your shop is.

"Fuel cost does not determine heating cost. One is at the start and the other at the finish of the operation. The way to lower the latter is to employ the furnace and fuel best suited to the operation and use both efficiently.

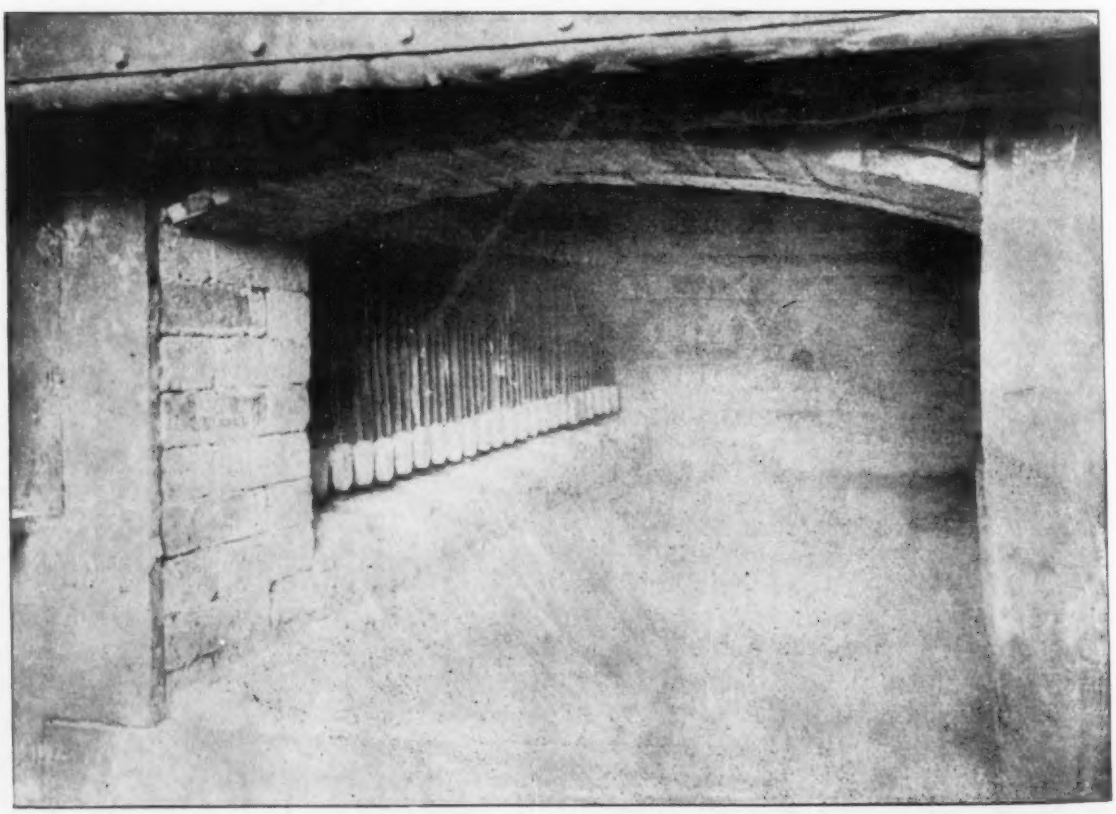

Fig. 5—Electric Carbonizing Furnace with Door Open. 79 Inches Deep, 36 Inches Wide, 29 Inches High, 60 Kilowatts, 220 Volts, 3 Phase, 925 Degrees Cent. Operation

"The B.t.u.'s you can get for a cent do not determine the quantity or quality of product you can get for a dollar any more than the price of kerosene determines the cost per ton mile of an automobile. It is the nature of the operation combined with the furnace that determines the fuel use."

DISCUSSION OF MR. COLLINS' PAPER

MR. DIEMER: Due to the fact I didn't get the focus on the chart I would like to ask the speaker what the cost of the electricity was at the high temperatures?

MR. COLLINS: That was the cost for one hundred thousand b. t. u. on the 100,000 b. t. u. basis.

MR. DIEMER: The rate per kilowatt?

MR. COLLINS: This is figured on a one-cent basis.

MR. CRUMBACKER: Do you know of any case where a forge shop uses electric furnaces for heating? Do you know of any company using electric heat for heating rough stock?

MR. COLLINS: I do not know of any company using it at the present time. Arrangements are being made for a test of the electric furnace in forging work.

MR. EVANS: I would like to ask the speaker if he has any general data on the type of furnace described as to the cost per kilowatt comparable to city gas in any given figures, that is, say take dollar city gas, what cost per kilowatt do you compare electricity on an equal basis?

MR. COLLINS: If these slides had shown up a little more clearly you would have seen that the answer to that is variable, depending upon your temperatures. A simple figure which will represent that can not be given safely, but I should be glad to show you these charts at any time, or if they should be printed, you will have an opportunity to check it up there. It is a question that cannot be answered simply by giving you rates, for it is misleading.

MR. EVANS: I thought perhaps you had a figure that was approximate for city gas, that is, in heat treating tool steel.

MR. COLLINS: No, that cannot safely be done unless you know all the conditions surrounding it. It would be simply folly to give you a figure, because it would not mean anything unless you know all the conditions surrounding it.

QUESTION: Do you know of any cases where the electric furnace might be placed in a wire mill?

MR. COLLINS: Well, coke would be the fuel used.

MR. HILLMAN: I would like to know whether the speaker knows of any research on the lines of electricity as heat for rotary furnaces?

MR. COLLINS: The question, as I understand it, is whether I know of any furnaces of the rotary type that are equipped electrically.

MR. HILLMAN: Whether any have ever been equipped that way and found unsatisfactory.

MR. COLLINS: I do not know of any of the rotary type that have been equipped and found unsatisfactory.

MR. HILLMAN: I never have been able to see any.

MR. COLLINS: There are furnaces operating of that type. Some of the most recent ones we have operating in Cleveland. I can readily refer you to people, later if you care to know who have them.

MR. HILLMAN: I have operated the rotary furnaces for some time, but I was wondering whether there was any possible comparison.

MR. COLLINS: Well, of course, there are different types of rotary furnaces. I am not sure to just what type of rotary you have reference. These of which I speak are the rotary disk type, the annular ring type. I am speaking of the type exhibited here by the American Gas Furnace Co., the rotary cylinder type.

MR. COLLINS: I have no data that I can give you on that type.

MR. STAFFORD: What is the largest chamber capacity of electric furnaces that you would use for annealing bulky material?

MR. COLLINS: I do not know whether I can give you the largest that has been used but I can tell you of some that have been used for heat treating. Some of the largest ones were used during the war for the heat treating of guns. At the present time the largest one is being constructed, which is something like 105 feet deep and cylindrical, 10 feet in diameter, and requires 2700 kilowatts for heating. That is a single furnace. We have other furnaces which were 6 feet in diameter, and 25 to 40 feet deep. Those are some of the larger sizes and kilowatts run all the way from 400 up to 700 and 800. There are others for somewhat lower temperature work installed in the Washington navy yard which required about 100 kilowatts to heat. Those had chambers 80 inches in diameter and were 88 feet long. Of course, there is nothing that stands in the way of building the furnace horizontally or vertically or of any chamber dimensions that might be required, or for any tonnage.

MR. THORNE: Is there any difference in the length of time that it takes between city gas and electric current for bringing a certain quantity of metal to heat?

MR. COLLINS: Ordinarily you heat stock more rapidly by radiation than you do by convection, and if you take the open fired gas furnace where a large part of your heating is by convection of hot gases as against the electric furnace where you are heating by radiation, you should get a shorter period for heating in the electric than in the gas furnace. If you take a gas furnace that has a muffle which does not restrict the flow of heat, in that case you would heat by radiation also, and your time of heating ought to be practically the same.

MEMBER: The all-important cost problem comes up and it is impossible to give comparative cost in general, but if we take definite furnaces and compare them, then the cost could be set. For instance, it would be very interesting to determine the fuel cost of an oil or gas-fired, continuous hardening furnace which puts through 100 pounds of hardenings per hour, and the kilowatt energy cost required for a corresponding electric furnace, both furnaces built by the best available concerns.

MR. COLLINS: That comes very near to being the conditions in this data which I gave. The furnaces described are operating on tools, dies, etc., with an output of 84 pounds, and in that case, with electricity at 1¼ cents and oil at 14 cents a gallon, the cost per pound of heating by oil is 70 per cent greater than the cost per pound by electricity.

MR. KAUFMAN: I would like to ask the speaker what is the life with temperatures not exceeding 1800 degrees?

MR. COLLINS: Speaking of the nichrome element, you want to know what the life of that is, running up to 1800 degrees Fahr. That is something that I can not tell you, since I have no data on it. We have

not had a breakdown at that temperature due to temperature. I might say that in furnaces which were installed about a year previous to the armistice, and which operated many of them night and day on the heat treating of gun forgings, the element running up around 1600 to 1700 degrees, at the end of that year's operation there was absolutely no way to detect that element differed in any way from the original element, either due to oxidation or crystal change by any method whatever that we could use to determine that there had been a change. Evidently it was identically the same as when it was first installed in the furnace, with the exception that the surface color was slightly darker. Of course, that metal is protected by a very adherent scale which forms a protection, and that scale had formed of course very early in the operation. You would not call it a scale, either; it resembles a barb wire finish. After the war in the construction of the large furnace, 105 feet, 2700-kilowatt, I was speaking about a few minutes ago, those same resisters that operated for this year in some of these temporary gun plants equipped with furnaces were reformed and put into the furnace along side new material. We actually did that, and when you can take old cloth that has worn a year and put it alongside new cloth and make a new garment of it, I think it speaks pretty well for the life of the resister.

PYROMETERS AND THEIR APPLICATION TO STEEL TREATING

By J. D. Andrews*

(A Paper Presented by Title at Philadelphia Convention)

Some years ago, when the layman using a pyrometer was not so familiar with "what makes the wheels go round", a customer telephoned complaining that an instrument recently purchased would not operate. To clear the trouble, we visited the plant and found to our amazement that he was endeavoring to measure the temperature by inserting into the heated zone the dial of an expansion pyrometer, rather than its stem. From the standpoint of pyrometer ethics, few manufacturers today would be guilty of an error of this kind.

Pyrometers today are an essential part of the equipment of progressive steel treating plants, although it is but a decade ago that a manufacturer was depending on the unaided judgment of the furnace operator, or had to reply on crude instruments for the determination of temperature.

While an observing man would with practice become expert in judging temperature by color, it was difficult to impart to others knowledge thus gained and ability to duplicate results necessitated good health on his part and freedom from light fluctuations. This latter consideration required excluding daylight from the heat treating room, so that during the short winter days, coming to the shop before sunrise and leaving after sunset, the operator might as well have worked in a mine, so far as daylight and ventilation were concerned.

But a few years ago, it was necessary to convince a manufacturer of the advantages of pyrometers compared with the rather crude methods then employed for measuring temperature. Today, he is educated to the value of

*District manager, Brown Instrument Co., New York.

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such instruments for the efficient operation of his furnaces, and is chiefly interested in the comparative merits of the equipment on the market.

Instruments for measuring temperature have been developed to operate on calorimetric, fusible cones, shrinkage, radiation, optics, and thermoelectric principles. The thermoelectric type is most widely used in the steel industry and consists essentially of three parts, namely, the thermocouple for insertion in the heated zone, the instrument proper for indicating or recording the temperature, and the connecting wires.

In each instance, the conditions to be encountered and the results desired govern calibration of the instrument, composition of the thermocouple rods and their protection, as well as composition of the leads and type of insulation. The instrument manufacturer provides apparatus accurate to within a small percentage, but operating conditions vary so widely, it is difficult and usually undesirable for him to stipulate working temperatures. When installing a pyrometer system, it is policy to study matters for a few days, noting that duplication of temperature, as shown by the instrument, invariably means duplication of results.

Thermocouples can be made very sensitive to temperature changes by using wire of small cross section having a low temperature coefficient. By using wire of large cross section, life can be increased but with the introduction of a time lag which in some works is objectionable. As stated above the thermocouple wires should be selected to meet the conditions of the particular work in hand.

Practically any two wires of different composition, when joined together and the junction heated, will generate a small voltage. In selecting wire for thermocouples, it must necessarily have ability to withstand the temperatures to be measured and must be of homogeneous material, generating high milivoltage constant in amount, so that temperatures may be duplicated. Experience has shown that the following combination of materials give good results for the temperatures indicated:

Materials	Upper Limits
Iron-constantin or nickel chromium constantin	1400 deg. Fahr.
Nickel-chromium-nickel-aluminum	2000 deg. Fahr.
Platinum-platinum 10 per cent rhodium	3000 deg. Fahr.

Platinum thermocouples generate but 20 millivolts at 3000 degrees Fahr. and this voltage usually is desirable for full scale reflection. As base metal thermocouples generate several times this millivoltage, ample torque is obtained with a lower full scale calibration; in addition they are more robust and but a fraction of the cost, hence their general use for temperatures below 2000 degrees Fahr. If properly protected and used below their upper limits, thermocouples will maintain their millivoltage and give good results. Where used near their upper limits, it is desirable that they be handled as little as possible as nickel tends to crystallize and iron to oxidize.

Base metal thermocouples are provided of selected wires, guaranteed to reproduce a given millivoltage within plus or minus 10 degrees Fahr. These couples have no satisfactory means of restandardizing and when they drop off in millivoltage must be cut back or discarded.

Some years ago the practice was adopted of shunting base metal thermocouples with manganin wire, reducing approximately two millivolts the normal potential at the terminals. This plan enables interchangeability and per mits restandardizing at any time by adjustment of the shunt, to within plus

or minus 5 degrees Fahr. Good results have been obtained, although, where extremely long thermocouples are to be used, there is theoretically some objection to this practice.

For constant use about 1800 degrees Fahr, thermocouples of platinum-platinum rhodium protected with tubes impervious to gases and mechanically strong are recommended. Heating these thermocouples by the passing of an electric current will restore them to normal when not too badly contaminated.

It is desired to keep the thermocouple wires protected from furnace gases and from oxidizing conditions in order to insure life. Protecting tubes used should be immune to the action of heat and chemicals, mechanically strong and good heat conductors. As it is only to a limited degree that we find all these qualities in any one material, it is of prime importance in choosing tubes to bear in mind the particular conditions to be encountered. Outside the furnace mechanical strength alone is necessary, hence, tubes of special material need protect only that section of the thermocouple in the heated zone, extending far enough through the furnace wall so that the balance of the couple, protected with a wrought iron tube, will not be injured by the heat or gases. This construction is a saving in expense as against the unnecessary use of full length tubes of special material.

It is recommended that where possible, base metal thermocouples be inserted eight inches or more into the heated zone, to prevent conductivity of the wires and protecting tube from reducing temperature of the hot junction in small furnaces this amount of insertion is not always practical due to the size of the chamber. Results, however, may be readily duplicated with less insertion, provided the couples are installed in a permanent manner. Duplication of results is usually of more importance than absolute temperature, for heat at best is only comparative and does not admit of direct measurement such as a mass which may be weighed or a length which may be scaled.

The welded junction between the two wires of the thermocouple is termed the hot end, and this is inserted at the point where it is desired to measure the temperature. This hot junction should be so placed in the furnace chamber as to be near the work under treatment but shielded from the flash heats of firing. Some endeavor to so place this end of the thermocouple that it may be seen through a sight hole in the furnace door, and thus enable comparison by color with that of the work being treated.

Where the temperature will not exceed 1300 degrees Fahr. these wires are insulated from each other with asbestos tubing or string painted with a solution of sodium silicate. Above 1300 degrees Fahr., insulation of lava or porcelain is to be recommended, as asbestos has a tendency to disintegrate, resulting in the possibility of the thermocouple short circuiting. For convenience in connecting with the lead wires, the outer or cold ends of the thermocouple are terminated at binding posts.

The electromotive force generated by a thermocouple is dependent on the difference between the hot and cold ends, hence it is desirable that the cold end be maintained at a constant temperature. To accomplish this result, compensating leads are employed similar to the couple, or of a material generating practically no millivoltage against the thermocouple wires when subjected to temperature changes. These join at the binding posts of the couple and extend to a point free from radiation or changes in atmospheric conditions. A constant cold end temperature may be maintained within a water or steam jacket at the end of a pipe well in the ground, or with a com-

pensating box temperature, of which is automatically held at a fixed point by a thermostat making and breaking the circuit of electric lamps within the box which furnish the heat.

At times the question has been raised as to whether the brass stud between the thermocouple and compensating leads would not cause incorrect results. No error occurs where the stud is the same temperature throughout its length, for then the positive millivoltage generated at one end is offset by the negative millivoltage at the other.

Thermocouples to be used in metal or salt baths are usually made up in right angle form so that the cold end is away from radiant heat and out of the workmen's way. The hot end should reach about midway of the bath. Thermocouples used in baths which are electrical conductors, or in furnaces having outer shells of metal, should employ double conductor wire and double arm switches to eliminate any possibility of one thermocouple interfering with another. Where inserted through a non-conducting material such as brick work, a single arm switch is satisfactory, permitting an individual wire to each thermocouple with a common return.

Wiring of an electric pyrometer system offers no fire hazard as only a millivoltage is generated by the thermocouple. It is good practice, however for the sake of mechanical protection and a neat, workmanlike installation to run this wire in conduit. Care should be taken to see that all joints are soldered and taped and that connections at binding posts are clean and tight. Where the wiring will be subjected to a temperature over 100 degrees Fahr. it is recommended that the insulation be of asbestos or of a slow burning material.

The LeChatelier type suspended coil galvanometer, for use as a thermo-electric pyrometer, was first made in Europe. In practice it was found that such delicate laboratory apparatus necessitated careful leveling as well as shielding from vibration, which led to the development in this country of a galvanometer system having a double pivoted rod form with steel pivots mounted in sapphire bearings. This construction made a more rugged shop instrument, but for some time the internal resistance was not above 10 ohms, necessitating in each instance, calibration for a given resistance of the external circuit.

Tests of these low resistance instruments have shown an error of as much as 18 degrees Fahr. when 50 feet of double conductor copper leads were subjected to a change in room temperature of 50 degrees Fahr., which made it desirable to use leads of No. 12-gauge B & S standard wire to keep down resistance of the external circuit.

Standard instruments today have the parts tooled up for interchangeability. They have internal resistance of some 15 ohms per millivolt, or over 600 ohms for a range of 2000 degrees Fahr. so that possible errors, compared to a 5-ohm instrument, are but 1-120th. With this internal resistance, a variation of over 3 ohms in the external circuit is permissible with an observable error of not over 0.5 per cent, equivalent to some 900 feet of No. 12-gauge double conductor wire.

By the use of an aluminum movable coil form, instruments are built with an internal resistance of 30 ohms per millivolt. The movable element is wound with enamel wire of but 0.003-inch diameter, which is much thinner than the silk insulated wire formerly used and permits more ampere-turns on a coil of a given width. The aluminum pointer is of tubing 0.012-inch out-

side diameter, 0.008-inch inside diameter, having a wall thickness of but 0.002 inch. The assembled movable element complete with pointer and springs, weighs but 526 milligrams.

Where the instruments are to be located near the furnaces that they may be consulted frequently by the attendant, as is common practice, it is important to keep the temperature coefficient as low as possible. Present construction has lowered this to about one-twelfth the former figure so that normal changes in room temperature will now cause no appreciable error.

An improvement in the wiring design of a millivoltmeter has been worked out by Messrs. Harrison and Foote of the bureau of standards, Washington. This permits balancing a series against a parallel circuit in the elimination of line resistance, no standard cell or other battery being required aside from millivoltage generated by the thermocouple. This principle may be applied to either indicating or recording instruments, although its field is chiefly as a portable, where line resistance is to be cared for but a rugged movable system with strong spring control is desired. When once adjusted for line resistance, this instrument is direct reading and shows readily fluctuations in temperature at the thermocouple which may be as much as a mile away.

The millivoltage generated by a thermocouple may also be measured by a potentiometer. While independent of resistance of the thermocouple circuit, the potentiometer like all instruments, has its limitations for the standard cell employed to regulate current in the battery circuit, is subject to deterioration if exposed to temperatures below 40 or above 150 degrees Fahr. In operation, the battery circuit must be balanced until its voltage offsets that of the thermocouple circuit, when no current flows through the galvanometer. These small batteries in time also wear out and require replacement.

An improved type of potentiometer has recently been perfected, so that a portable instrument can now be provided with a scale length of approximately 96 inches, permitting graduations of 1-50 millivolt for a full scale of 50 millivolts. This scale is made in the form of a spiral and is direct reading, being automatically adjusted to position as the slide wire resistance of the battery circuit is balanced against the millivoltage of the thermocouple. This potentiometer is supplied with a standard cadmium sulphate cell, having an unsaturated solution and neglibible temperature coefficient. It conforms to recommendations and specifications of the bureau of standards.

A pyrometer system may be likened to a chain, the strength or accuracy of which is but equal to its weakest link; hence, when going in for closer than commercial accuracy, all factors should be strengthened.

It has been the practice in the past when installing pyrometers to locate the indicating instrument near the furnaces for ready reference by the operator, recorder instruments being placed in the office of the superintendent that he might supervise and study the furnace temperatures.

Economy of furnace time frequently makes it desirable to carry the temperature higher than the work should ever reach, so that timing the period of heating is only secondary in importance to the temperature of the furnace. As recording instruments give a time temperature check on heat treating operations, they are daily coming into greater use in the shop. Their use by the operator enables closer regulation of temperature, for he may note the tendency to vary from normal and check such changes at the start.

One automobile firm has installed near the furnaces for guidance of the operators some 30 recording pyrometers of the duplex type, a number of which are used in connection with lead hardening of gears. There is a sharp drop in the temperature recorded when a cold charge is placed in the pot, hence, the chart serves as a production record to show the number of charges treated in a given time. Experience has shown that these records stimulate friendly rivalry between furnace operators, that an inexperienced man working alongside an expert can quickly improve his product, and that the record chart will insure each batch of work heated in accordance with instructions.

Recording pyrometers employ a clock mechanism to time the feed of the chart and to operate the depressor mechanism. These instruments were originally designed to mark with pen and ink and depended on capillary action to feed the ink from a small reservoir carried by the pen arm. It was difficult to so balance the delicate movable system that it would read correctly with the ink reservoir either full or empty, and changing atmospheric conditions caused the ink to dry and clog the pen, or to become fluid and feed too rapidly to the chart.

A sensitized chart was next tried, where the pen marked through an emulsion or coating. This idea has likewise been abandoned, for the pen had a tendency to collect emulsion and adhere to the chart, and if the latter were brought near a radiator or other warm object, the record would be destroyed.

As made today, the disk chart recorded employs a transparent chart backed by a carbon. A white sheet is interposed between the two so that while in operation, the record may be readily seen in contrast against the white background. No fixing solution is required to make this record permanent and it is ready for file as removed from the instrument.

The depressor mechanism, as operated by the clock, forces the stylus against the chart surface once a minute or oftener, leaving a carbon mark to show its position. Between depressions the stylus is free to assume changes in position as the thermocouple hot junction changes in temperature.

A recorder in far greater demand today, employs a strip chart which has numerous advantages over the disk chart instrument just described. Throughout the range, these charts have uniform time spacing of 1⅛ inches per hour. The stylus is depressed at regular periods by the clock mechanism onto a carbon marking band which passes over the chart similar to a typewriter ribbon.

The position of the stylus at the instant is shown by the dot left on the chart; this may also be read on the indicating scale attached to the depressor bar. As these dots occur once a minute or more frequently, a complete time temperature record is made without friction from the pen trailing. Both chart and carbon marking ribbon operate for 60 days without replacement but the chart may be torn off for any period where it feeds through a slot at bottom of the instrument case.

This instrument is provided with a hardwood protecting case of dust proof construction, having a 7-inch space beneath the instrument proper into which the completed chart drops. A reroll attachment for the chart can be furnished where desired to operate from the clock mechanism.

This strip chart instrument is equipped with a doublebarrel spring clock especially designed for uniform power. This clock has the well known Se

Thomas escapement, is mounted in a separate dustproof metal compartment with plate glass front, and arranged for winding from outside the instrument case. Means are provided for stopping and starting and for adjusting the timing. With this construction, the operator has little occasion to touch the instrument mechanism, which minimizes the chance of his disturbing the balance of the movable system.

Where temperatures relate to each other, it is often desirable to have two or more records on one chart for comparative purposes. This need has developed the duplex type recorder, in which two pens with separate galvanometer systems operate on a single chart through a marking ribbon as described above.

Further development has brought out the multiple recorded, making from one to 10 records on a chart. This instrument likewise employs a carbon ribbon for marking, but in this instance five colors are used. Records one to five are made with a single dot of the stylus, while records six to 10 are made with double dots, repeating the color scheme. The clock mechanism, in switching the galvanometer from one thermocouple to another, likewise shifts the width of ribbon in order to give a distinguishing color for each record.

Where an operation is to be duplicated repeatedly, it is often desirable to trace lines on the charts to show the allowable variations thus enabling the operator to more readily follow instructions. These lines of course, can be included when printing the charts.

Loss of record would naturally result if the attendant neglected to wind the spring clock. Today, however, an electrically-driven clock can be supplied with any recording instrument.

During the war, certain industries had difficulty in securing men able to use pyrometers with intelligence. To meet this condition, a battery of red, white and blue electric lights was installed over each furnace, to indicate high, normal and low temperature. Where mounted in a vertical position, all concerned could see from a distance which furnaces were operating above or below normal, the lights being controlled by an operator at a central station switchboard, held responsible for maintaining the correct temperature in all furnaces. This system was chiefly adapted to day-in and day-out operation on work requiring long period heats.

In some installations the white light was used in combination with the red, to indicate a given number of degrees above normal, and the red light only when this safety zone was exceeded. The same combination with the blue light covered temperatures below normal.

A development of this system eliminates the central station operator, as the lights may now be automatically controlled by relay circuits actuated by the instrument. It has been but a step further to employ these relay circuits to actuate electric switches or valves, so that temperatures may be automatically controlled whether the source of heat be electricity, steam, gas or oil. Control is possible within one per cent of the scale range.

Control of electrically-heated furnaces merely requires opening or closing a circuit or the operation of a rheostat. This has been comparatively simple and numerous installations have been made.

Control of steam-heated equipment is similar to that of gas-fired furnaces operating on the single pipe system and is less complicated than that in which the valves must operate simultaneously on both gas and air. Gas control is

working out well at a number of plants and the records show closer regulation than has been possible with hand control.

Control of oil-fired furnaces requires but a minute adjustment of the valves to alter the temperature, hence, proper filtration of the oil is of prime importance to prevent clogging. A number of installations of this type which look very promising have been made and the weak spots are being gradually eliminated.

With any installation for automatic control of temperature, the conditions must be studied and the equipment so adapted as to give the results desired.

Conditions obtain where the temperature to be measured is so high that directly inserting thermocouples in the heated zone would give but very short life. In other cases, one could not very well reach with the hot junction of a thermocouple, so that it is necessary to employ either optical or radiation pyrometers.

A radiation pyrometer consists of a sensitive thermocouple placed in the focusing point of a concave mirror at the rear end of what is termed a radiation tube. The rays of heat from the furnace strike the mirror and are brought to a focus on the hot junction of the tiny thermocouple, the millivoltage generated being measured on a direct-reading instrument.

Optical pyrometers depend on comparison of light or color with the object under treatment, thus there is the personal element with which to contend. With either radiation of optical instruments, correct readings depend on a fairly clear atmosphere, so opaque gas would interfere with true radiation, as would also intervening flames of temperature higher than the object to be observed.

A recording pyrometer has been designed to show graphically the temperature at which steel goes through the molecular changes termed transformation points. The instrument proper is a recording millivoltmeter with a movable coil wound in differential. It is operated with two thermocouples, one of which registers true temperature, while the second traces an arbitrary curve and is so connected that its millivoltage is opposed to that of the first couple by means of an automatic switch operated by the clock mechanism.

On a rising temperature, steel has a tendency to absorb heat during the change in its molecular structure and on a falling temperature to give up heat. These transformations are termed respectively the decalescent and recalescent points.

The first couple is embedded in a sample of steel to be tested shaped to a size about 1-inch long by -inches diameter, with a hole in one end ⅝-inch deep by 7/32-inch diameter. The second couple is embedded in a nickel alloy or neutral body of similar size which has no transformation point. These are placed together in a small electric furnace and brought to heat.

The thermocouple millivoltage varies with temperature of the body in which it is embedded, hence, there is a sharp deviation in the curve of the neutral body couple where the transformation points occur. The true transformation temperatures are read from the curve of the test couple at the time when the deviation starts on the curve of the neutral body couple.

This instrument can readily be equipped with an automatic cutout, adjusted to open the furnace circuit when a given temperature is reached, thus

permitting the entire test to be run off automatically when once set in operation. With an instrument of this type, the manufacturer can provide specifications as to the most desirable heat treatment for steel of a given composition.

In all heat treating work, pyrometers are of material aid to efficient operation, for with them the operator can intelligently follow the steel manufacturer's specifications and at the same time save fuel consumption and upkeep of the furnaces.

From the standpoint of fuel saving alone, pyrometers should save sufficient to more than warrant the installation, for the tendency without a gage is to operate at higher temperatures than necessary. An installation costing $600 requires a saving of but $10 per month, or as small an amount as 40c per working day to return 20 per cent on the investment.

Many firms have the mistaken idea that a pyrometer will prove a cure all for the ills of the heat treating department and that when once installed it requires no further attention. Pyrometers have limitations which should be recognized, hence, their use should be seasoned with judgment, for like the steam gage on a boiler, they but guide the operator to more efficient use of his equipment.

Plants having pyrometer installations of any size, should assign an intelligent man to complete charge of the equipment, for in case of necessity, it is desirable to have available one familiar with the apparatus rather than to leave such a matter to chance. Instances are numerous where a man unfamiliar with the equipment has taken the instruments apart and caused considerable trouble, the original difficulty being nothing more serious than a burned out thermocouple or loose connection. To prevent such tampering it is customary to seal instruments as they leave the factory.

To render prompt assistance in case of need, a service department is maintained by one of the instrument companies with traveling representatives attached to the district offices. When help is requested, these men call at a client's plant and check the pyrometers, making suggestions as to their efficient use. Some clients arrange with this department for periodic inspection and check of their equipment, and where the size of their installation does not warrant training one of their own men, this is recommended as good insurance. Where the installation is of sufficient size, the instrument companies are pleased to train at their factory, men assigned to care of the pyrometers, no charge being made for this service.

Standard checking equipment consists of a small electric furnace with rheostat control, a double scale portable instrument having a range of 20 and 40 millivolts, or equivalent in degrees, a thermocouple of platinum rhodium, a secondary standard couple of base metal and a switch.

The electric furnace should be some 12 inches deep and of sufficient diameter that several service couples at a time, removed from their protecting tubes, may be heated with a secondary standard yet kept equidistant from the furnace walls. Care should be taken that the hot junctions of the couples are together, and that they extend 6 or 8 inches into the furnace to prevent loss of heat by conduction.

The electric furnace, when brought to the temperature desired, should be held constant at that point for some minutes before readings are taken. It is desirable that a check be made at or near the normal operating temperature

of the service couples. The switch will enable quick connection of any thermocouple with the checking instrument.

In place of an electric furnace for standardizing the thermocouples, some prefer a small crucible of pure salt or pure metal. Pure salt is obtainable at any chemical supply house and should be raised to a temperature of about 1550 degrees Fahr. before inserting the thermocouples. There is a noticeable lag when the salt solidified or freezes, and the pyrometer should then read 1474 degrees Fahr. Tin, zinc, antimony, silver, copper and gold may be used for this work, their melting points being respectively 450, 787, 1166, 1761, 1981 and 1945 degrees Fahr.

Frequently equipment which works out well on laboratory tests requires alterations to meet service conditions. An instance of this kind is the disk chart recorder, in which the galvanometer system is mounted on the door of the case and swings away from the chart when the door is opened. It was found in service that the operator, when replacing the chart, often opened the case but 90 degrees, with the result that his sleeve engaged with the stylus, unbalancing the entire system and entailing considerable repair work. This trouble has been largely overcome by hinging the door at the left instead of at the right side.

In developing apparatus for measuring temperature, as in all lines of progress, one improvement merely paves the way for other refinements not previously foreseen and perfection lies just a step in advance. In this development work, it is largely men in the heat treating field who must be thanked for co-operation in working out the problems as they arise.

HIGH CARBON OPEN-HEARTH STEEL VERSUS CRUCIBLE TOOL STEEL IN THE MANUFACTURE OF MISCELLANEOUS TOOLS

By George Porteous*

(Paper presented by Title at Philadelphia Convention)

This subject should be of general interest because of the fact that the purchase of tool steel for general tools, such as hand and pneumatic chisels, shear blades, etc., is a large item in the yearly expense bill of many manufacturing establishments. The substitution of high carbon open-hearth steel in place of the more expensive crucible tool steels in the manufacture of these classes of tools is not a recent departure from established practice, but this subject in the past has not received the serious consideration which it merits.

It is axiomatical that the quality of open-hearth high carbon steel can not be compared fairly to that of the more carefully made electric and crucible tool steels, therefore, it is obvious that the forging and thermal treatment of the lower grade steel must be studied carefully in order to compete against the higher grade steels in the manufacture of miscellaneous tools.

I have before me several publications showing advertisements of special tool steel made into punch and chisel form, driven through steel blocks of from 1 to 2½ inches thick. This illustration purports to show that the steel from which the punches and chisels were made is of special quality and far ahead of any ordinary tool steel on the market. As a matter of fact, this is not a quality test at all, a sample of high carbon open-hearth steel can

*Supervisor of forge and heat treatment, Minnesota Steel Co., Duluth, Minn.

be made into a similar punch to that shown in the illustration, treated and drawn through a 3-inch block of medium carbon steel. An example of this is shown in Fig. 2.

From the foregoing example, we learn that high carbon open-hearth steel can be so treated that it will equal the durability of a so-called superior grade of steel by means of careful and intelligent treatment, and we can also realize that this characteristic also opens up a very large field of usefulness by the substitution of this steel in place of the high grade steels in the manufacture of many kinds of tools.

We have been using high carbon open-hearth steel as a substitute for tool steel for several years and we have been successful in its treatment for such tools as cold chisels, rivet snaps, punches and dies, taps, shear blades, and similar tools. The grade of steel that has proven most successful in the

Fig. 1—Several Types of Tools Made from High Carbon Open-Hearth Steel

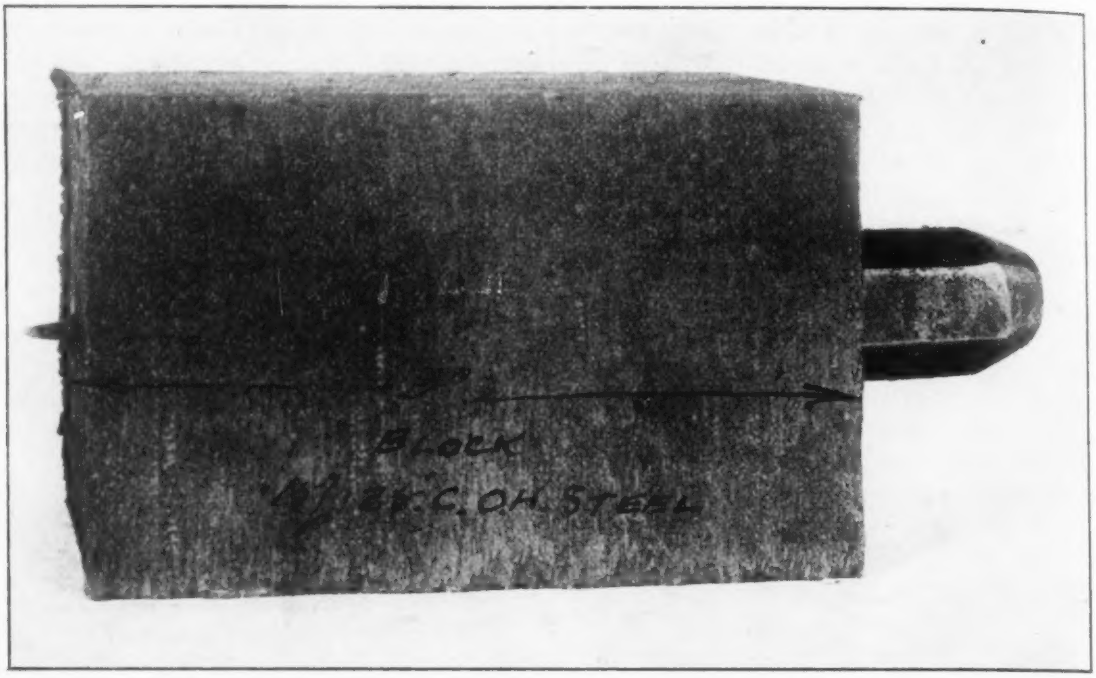


Fig. 2—Punch Made from High Carbon Open-Hearth Steel Piercing a 3-Inch 0.15-0.25 Per Cent Carbon Open-Hearth Steel Block

manufacture of these classes of tools has had an analysis of approximately 80 to 100 per cent carbon, less than 0.03 phosphorus, less than 0.03 per cent sulphur and 0.35 to 0.45 per cent manganese.

To get the best results for a steel of the above composition, great care is necessary in the heating and forging operations as well as in the subsequent thermal treatment. The billet from which the steel is drawn down should be at least twice the diameter of the finished forging. For example, ¾ to 1-inch octagon should be forged from not less than a 1½-inch bar or billet. The forging temperature should be from 1800 to 1950 degrees Fahr., reheated as required depending upon the rapidity of the forging operation and the dimensions of the finished bar. As the forging approaches the final stages, the hammering should become more rapid with lighter blows to finish the forging of the steel at a temperature of about 1350 degrees Fahr. which refines the grain and leaves the steel in better condition for the subsequent heat treatment.

The refining and equalizing process of steel treatment as applied to the forge and heat treatment of percussion tools such as cold chisels, hand and pneumatic, made from open-hearth high carbon steel is applied to the steel in several progressive stages, the success of each stage of the treatment depending upon the proper carrying out of the preceding one.

The first stage in the evolution of a cold chisel is the forging operation which in order to ensure success in the finished product must be done intelligently and with due attention to the proper forging temperature. The steel should be heated high enough to be in a thoroughly plastic condition, approximately 1850 to 1950 degrees Fahr. The closer the heat is to the higher temperature the better, so long as a reducing and not an oxidizing heat is obtained. At this stage it is well to remember that when forging the point of a chisel, the edges should not be hammered after the point has been

forged thin, because if the steel has been thoroughly worked down to a thin edge on the flat and then turned up and hammered on the edge, the force of the hammering will affect the grain of the steel on the edges but will not penetrate to the center, thereby causing the grain structure of the steel to be uneven. This will cause the steel to develop water cracks when hardened.

The proper method of forging the point of a chisel is to work the steel down to a square taper, as in the forging of a diamond point chisel and then flatten out to the desired width. A little practice will enable a person to gage the amount of stock required to forge the point of the chisel so that there will be little, if any, grinding to do on the edge. The rough point of the chisel should be trimmed off with a hot chisel immediately following the forging operation when the steel is at a cherry red heat. If necessary the chisel should be reheated.

The second or refining stage of the treatment is done by light blows with a hand hammer, the face of the hammer being dipped in water once or twice during the operation, on the flat of the chisel point when at a dark blood red heat.

The third stage of the treatment is the equalizing of the steel at the point of the chisel. The steel should be allowed to cool down to about 750 degrees Fahr., when the red disappears in the dark, dipped in black oil, withdrawn, and allowed to cool down slowly to atmospheric temperature. The oil should be at a temperature of about 125 degrees Fahr. for this purpose.

If the forging, refining and equalizing operations as just explained have been followed carefully, the grain structure of the steel will be in a state of equilibrium and in perfect condition to be hardened and tempered.

The hardening temperature should be the lowest possible consistent with the holding of the martensitic condition of the structure when heated over

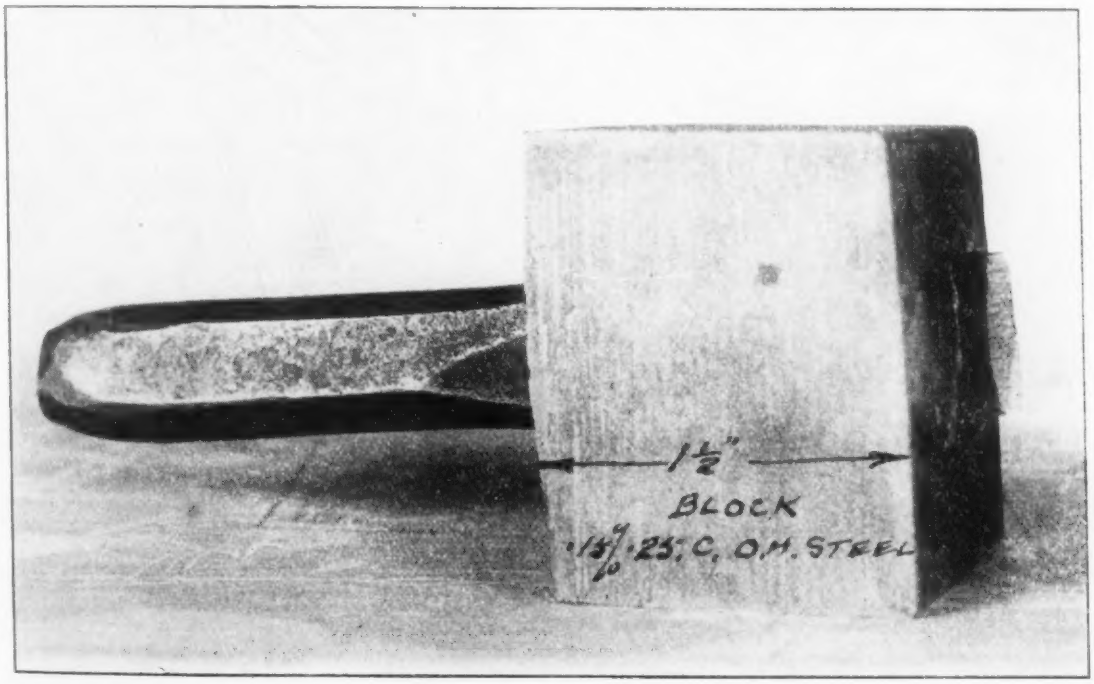


Fig. 3—Chisel Made from High Carbon Open-Hearth Steel Penetrating a 1½-Inch 0.15-0.25 Per Cent Carbon Open-Hearth Steel Block

the decalescent point of the steel. This would be about 1425 degrees Fahr. The point of the chisel should not touch water after the first chill. Check the rising temperature in oil when drawing temper by the color method. If an oil tempering bath is used, the temperature for this class of tool would be 490 to 500 degrees Fahr. for a period to be determined by the character of the work to be performed.

In cases where the structure of the steel at the points of cold chisels and kindred tools has been impaired by reason of overheating or cold working, it is possible to restore the steel to its original state by upsetting and rewelding the part affected, using a flux of common dry yellow clay. This flux prevents the atmospheric oxygen from finding its way through the pores of the metal and combining with the carbon, forcing the crystalline grains apart, and destroying their cohesion when heating the steel to the high temperature necessary. This, with the subsequent thorough hammering and working, will restore the steel to its original state. The shanks of pneumatic chisels are treated by being heated to 1450 degrees Fahr., dipped all over in cyanide of potassium, and cooled in oil with no further treatment.

Many of our scientific steel experts will be shocked at the crudity of the above treatment, nevertheless, it is the only treatment that gave maximum service on the shanks of chisels used by us for the chipping of hard steel billets.

The adaptability of using high carbon open-hearth steel in the manufacture of pneumatic chisels for chipping hard steel has been tested very thoroughly in the chipping and dressing of shell steel bars and billets. We have tested it against some of the more expensive steels on the market and it has given us just as good service as these high grade steels and as a consequence, we have adopted high carbon open-hearth steel exclusively for this class of tools.

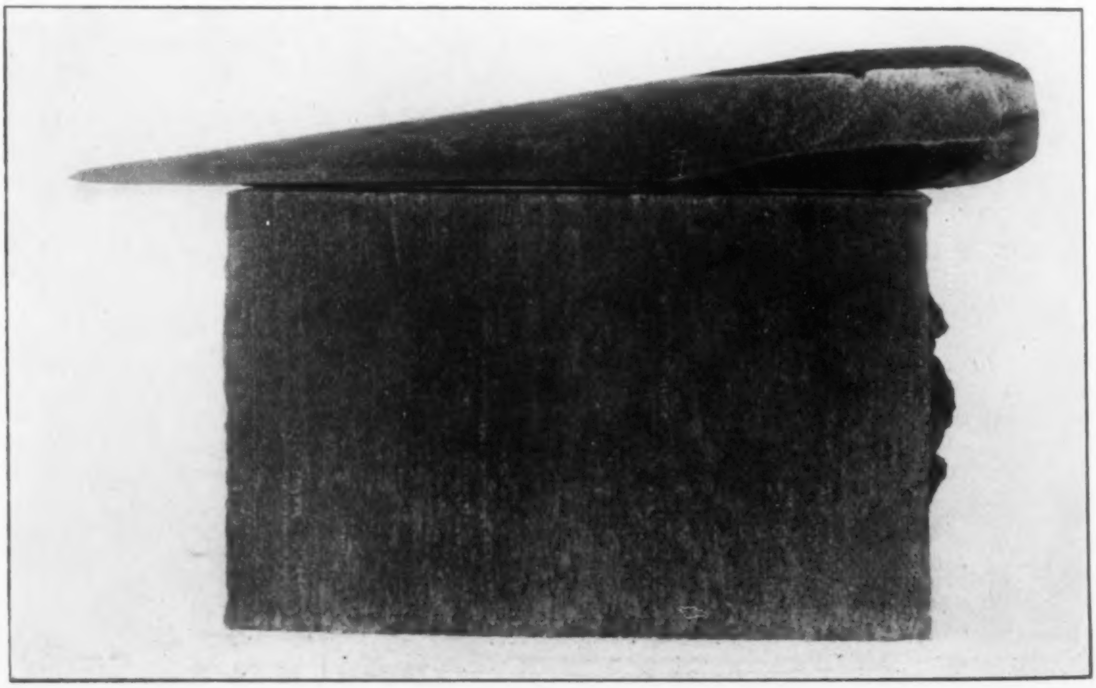


Fig. 4—Chisel and Block Are Both Made from the Same Material, High Carbon Open-Hearth Steel. The Chisel Has Had Special Heat Treatment

The approximate analysis of open-hearth high carbon steel for taps and reamers should be approximately the following: 0.90 to 1.10 per cent carbon, not over 0.02 per cent phosphorus, not over 0.02 per cent sulphur, and 0.25 to 0.35 per cent manganese. The steel should be forged at a temperature of 1750 to 1900 degrees Fahr. annealed at 1425 to 1475 degrees Fahr. in a muffle furnace or in covered receptacle to prevent access of air, or withdrawn when the proper temperature has been reached and covered with dry lime or ashes.

When the tools have been rough machined they should be equalized as described in a former paragraph. This equalizing process acts as a preventive to the warping of the tools in the subsequent heat treatment. The hardening temperature of this grade of steel is 1400 to 1425 degrees Fahr. To obtain maximum cutting qualities combined with toughness and resistance to shock, the best method of hardening treatment is to hold the tap or reamer in the water just long enough to harden the teeth or cutting faces and then immerse quickly in oil and allow the center of the tool to cool down slowly. The oil immersion allows the hard surface of the tool to heat up enough without losing hardness to take care of the cooling strains which would be liable to crack the tool if allowed to cool off entirely in the water. The drawing temperature is from 400 to 425 degrees Fahr.

The analysis of high carbon open-hearth steel found to give the best results in the manufacture of shear blades for cutting cold metal such as steel plate and bar stock is within the following limits: 0.85 to 0.95 per cent carbon, not over 0.03 per cent phosphorus, not over 0.03 per cent sulphur, and 0.30 to 0.45 per cent manganese. Steel that has been forged for shear blades should be annealed at 1450 to 1500 degrees Fahr., heated evenly in a muffle furnace and allowed to cool down with the furnace.

The hardening temperature is 1425 to 1450 degrees Fahr., chill in water

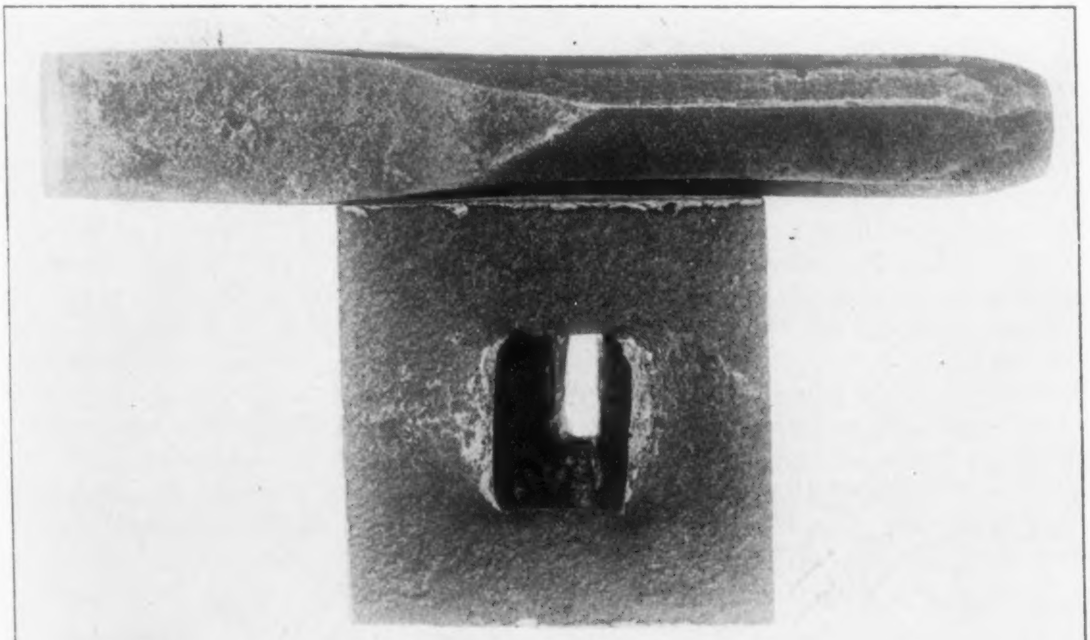


Fig. 5—End View of Steel Block Showing the Clean Cut Hole Made by Driving the Chisel Through It—This Is the Same Block Shown in Fig. 4

and allow to remain in the bath long enough to harden the exposed surfaces, then transfer to an oil bath and allow to cool down in the oil, draw in oil tempering furnace to 490 to 500 degrees Fahr. Allow the blade to remain in oil tempering furnace long enough to ensure thorough toughening. A shear blade of the following dimensions, 1½ x 7½ x 24 inches, should be allowed to remain at the proper drawing temperature for a period of at least two hours. To secure the best results in service from a high carbon open-hearth shear blade, the center of the blade longitudinally through the hole centers should be left as soft and tough as possible by being protected from the action of the quenching medium. This can be done by putting a bolt through each bolt hole with a washer on each side of the blade and the bolt and washer luted with clay. In the case of large size shear blades, the best method is to use two flat strips ⅜-inch thick and of suitable width, drilling holes in the strips to match the holes in the shear blades, luting with clay and holding them in place with suitable bolts. Care should be taken that the strips do not cover the cutting edge of the blade. In the case of a shear blade 9 inches wide, the strip should be 4½ inches wide. We have never had a shear blade to break either in hardening or in service when protected in this manner.

I have already mentioned in an earlier paragraph that the punch test is not an indication of the superior quality of the steel from which the punch is made, but is rather a problem in heat treatment. This drive test can be made by using either open-hearth high carbon or regular crucible tool steel. The analysis of the high carbon steel punch shown in Fig. 2 is as follows: 1.03 per cent carbon, 0.27 per cent manganese, 0.013 per cent phosphorus, and 0.032 per cent sulphur. The block through which the punch is driven is made of open-hearth steel of 0.15 to 0.20 per cent carbon. The punch is exactly as it was after being driven through the block, it has not been touched up in any way, the chisel which is driven through the 1½-inch steel block is taken from the same bar that the punch was made from. A chisel is much harder to drive by reason of the difference in the size and shape of the point and the finer the point of the tool the easier it is to drive.

High carbon open-hearth steel can not be made to take the place of high grade crucible steels for certain classes of tools such as some forms of milling cutters and intricate blanking dies because the cost of the workmanship in making and finishing these classes of tools overbalance the first cost of the steel to such a large extent that it would not be justifiable to use anything but the very highest grade of special alloy steel in their manufacture, but high carbon open-hearth steel can be used in the manufacture of tools some of which I have enumerated, and will give just as much satisfaction in service as the higher grade steels. There is another point in favor of the use of open-hearth high carbon steel as against the crucible steels and that is the difference in price. The cost of open-hearth steel is around 3 cents and crucible steel from 12 to 17 cents per pound. This considerable difference in price should be an incentive to the more general use of open-hearth high carbon steel.

I have investigated this matter thoroughly and I can guarantee that just as good results can be secured by the judicious use of open-hearth high carbon steel with the proper heat treatment as can be secured from the use of a higher grade and more expensive tool steel.

ROLE OF THE METALLURGICAL LABORATORY IN RELATION TO INSPECTION

By Marshall Medwedeff*

(Presented by Title at Philadelphia Convention)

What should be the relation of the metallurgical laboratory to the operating organization in general and to the Inspection Department in particular? A number of modern organizations have answered this question satisfactorily and have delegated to the metallurgical department such functions as properly lie within the scope. But it is for the benefit of such organizations in which the metallurgical department or laboratory is still groping to find its place and maximum usefulness, that this paper is intended. Heat treaters are familiar with the unenviable place the laboratory occupied until very recently and it is owing largely to the automotive industry that the metallurgical laboratory in particular has acquired the importance it possesses today.

The maximum usefulness of the metallurgical department in an organization will depend upon several factors: The support and confidence of the management; the co-operation and non-prejudice of the operating department to what they often term "the white collared force" and last but not least, upon the practical experience and level-headedness of the metallurgist in charge.

It is one of the unfortunate handicaps of the metallurgical fraternity that concerns wishing to be up-to-date secure a so-called metallurgist either just out of college or one with very little practical experience, who neither has the accumulated knowledge of years of experience nor the mental balance acquired as a result of this experience to be of serious use. When all the factors mentioned above are positive, then the metallurgical department should be an asset to any organization and its activities reflect in a balance in the ultimate reckoning on the books of the company.

It was always within the scope of the metallurgical laboratory to test raw and finished materials. It made reports of its tests and there usually its functions ceased. Fortunately for industry, a broader spirit and a more liberal attitude has developed within the last few years toward the laboratory, until today it is called upon more and more to take an active interest in production and well-trained experienced metallurgists are called upon to take charge of heat treating and forging departments.

With the advent of high speed steel tools, the manufacturing of interchangeable parts, and the production of alloy steels, shop practice has been revolutionized. The manufacturing of interchangeable parts calls for rigid inspection and today we have well developed inspection departments frequently functioning separately from the production department and responsible to the management. The functions of the inspection department are inspection of raw material such as bars, forgings, castings, etc., inspection of the product through the various stages of manufacture and last of all, final inspection.

The metallurgical laboratory is interested, or should be permitted to be interested, in all these stages. The manufacturing organization through

*Metallurgical engineer, Samson Tractor Co., Janesville, Wis.

its engineering staff should look to the metallurgical laboratory to specify the materials to be used for manufacturing different parts, the condition of these materials in their raw stage, referring particularly to the machine ability as determined by brinnel and shore hardness numbers. The laboratory should set the limits for these numbers to be followed by the inspection department in routine inspection. The experienced metallurgist with his expert knowledge of the physical fitness of materials, correlating his metallurgical knowledge with good shop practice, should be the person best qualified to specify the proper hardness for materials which would machine well and at the same time enhance production. There has been and still is, much guess work in this matter and no attention is paid to this phase of the metallurgist's usefullness.

In inspecting raw materials such as forgings, castings, etc., the inspection department must see that these materials conform to the specifications for such materials developed in the metallurgical laboratory. When such materials are manufactured within the home organization, it should be the duty of the metallurgical laboratory to see that these materials are manufactured in accordance with these specifications. Whenever the inspection department reveals considerable variations from the established standards, the laboratory should be called upon to investigate the causes and remedy, if possible, the manufacturing conditions responsible for these variations.

In case such products are purchased from an outside manufacturer, any complaints on quality or physical condition of these materials should be turned over to the metallurgical department. The metallurgist should take up these cases with the proper authorities at the source of manufacture, as his familiarity with the technical details of the processes involved should enable him to deal intelligently in each case, and settle any controversies that might arise to the satisfaction of all concerned. He may, if necessary, suggest remedies or improvement in practice that would help materially in eliminating defective material or product not up to specifications.

Upon the metallurgist's advice the home plant should, whenever possible, put the material rejected through such processes as will make it serviceable, penalizing the original source by charging it up with the cost of the work, such as annealing in case material is too hard and unpracticable for good production, and reheat treating of forgings in case they are too soft. The above, of course, by mutual agreement of the contracting parties, is suggested as it saves freight charges as well as time.

Regarding the metallurgical laboratory's interest in inspection through the various stages of manufacture, the laboratory is not interested primarily in the rejection of machined parts due to careless workmanship or faulty layout except in a general way, but it should be decidedly interested where the bad workmanship is a result of the physical condition of the material or faulty tools. Whenever the inspection department is compelled to reject partly finished parts which in their judgment is not due to carelessness, the laboratory should be called upon to investigate the cause of the trouble. It might find that the material is either too hard or too soft, or tools too soft or made of unsuitable steel for the particular job, or badly heat treated. Such occasions are not rare in modern machine shop practice.

Finally, the laboratory's interest in final inspection extends only as far as the general appearance and final physical properties and to such mechanical

nonconformities as are traceable to the metallurgical operations through which they passed in the heat treating processes, such as distortion, shrinkage, cracking, etc. The laboratory should study all such cases with a view of eliminating or reducing the rejections due to the above causes. The laboratory should specify the final physical properties of the finished product wherever, owing to service requirements, such properties are important. It should cooperate with the inspection department in devising routine methods of inspection.

This outline is necessarily general in nature but I have endeavored to state briefly what the relations of the metallurgical laboratory and the inspection department should be in a modern organization. They should at all times work together in eliminating the scrap pile. The laboratory must be ready to unravel the ills that metal absorbs through the manufacturing processes, find the causes for these ills and remedy them whenever possible. The function of the two should at all times be mutually helpful and work in the final analysis for the common interest of the organization.

EFFECT OF PHOSPHORUS AND SULPHUR ON STEEL

By E. W. Rettew* and L. A. Lanning*

(Presented before Hartford Chapter)

Phosphorus

Phosphorus is probably the most injurious impurity found in steel with the possible exception of the occluded gases such as oxygen, hydrogen and nitrogen. In the rolling mill the phosphorus shows no evil effects, the heat required for rolling apparently overcoming its detrimental qualities. In tin plate bars a small amount is necessary to prevent the sheets from sticking together in the rolling.

The ill effects of phosphorus are very apparent when the steel is cold. It produces the phenomena of "cold shortness" or brittleness when cold either in hardening or annealed steels. This brittleness is especially noticeable when the steels are subjected to vibratory stresses or to shock. In the tensile test the ductility is very little affected when the loads are slowly applied. Experiments apparently have proved that in amounts up to 0.12 per cent, phosphorus increases the strength under slowly applied loads. Under shock, however, this material was a failure. The bad effects of phosphorus increase as the carbon content is increased due to the formation of coarse crystals which produce brittleness.

The phosphorus produces a phosphide of iron, Fe_3P, which forms a series of alloys with iron. The eutectic of the series contains 64 per cent of the phosphide or 10.24 per cent of phosphorus and is very brittle. A small amount of phosphorus will dissolve in the iron forming no brittle eutectic, but as the carbon is increased it precipitates the phosphorus from the solid solution into the brittle eutectic form. Thus the lower the carbon the more phosphorus which may be present without being seriously injurious, but with each increase in carbon the phosphorus must be correspondingly decreased to prevent the eutectic formation with its coarse crystallization and brittleness.

Phosphorus increases the tensile strength of steel somewhat as does

*New Departure Mfg. Co., Bristol, Conn.

carbon, but does not decrease the ductility as measured by the tensile test as rapidly as does carbon. Phosphoretic steels resist wear better than steels with a lower phosphorus, and high phosphorus is permissable or even desirable if the steel is to resist abrasion only and no shock or vibration is to be encountered. Phosphorus increases the hardness of steel without lowering the electric conductivity as much as other hardening elements. High phosphorus steels are often used for third rails of trolley systems because of this property.

High phosphorus steels, 0.13-0.20 per cent are used largely for screw machine products where shock strength is not a requisite as it gives excellent machining properties, producing clean, bright surfaces and increasing the tensile strength. Phosphorus increases the rigidity of steel, reducing the deflection, but is unfit for structural purposes due to its inherent brittleness. Phosphorus also increases the resistance of steel to corrison.

One per cent is considered high in a low carbon steel or a low grade steel, while 0.08 per cent is considered a good grade of low carbon steel. The higher carbon grades contain 0.04, per cent, or under, while in tool steel it is usually kept under 0.03 per cent. As a rule, the permissable percentage of phosphorus is inversely proportional to the percentage of carbon.

Carbonizing steels should be low in phosphorus when strong objects are desired. These pieces should be carbonized in raw bone, due to its high phosphorus content. In wrought iron a certain amount 0.10-0.15 per cent is permissible and even desirable, especially if the iron is to be used for structural purposes, as such an amount does not produce the coarse crystallization near welds and the carbon is low tending to add to the strength of the metal by replacing the carbon without brittleness when carbon is present.

Sulphur

Sulphur is present in steel in two forms, iron sulphide and manganese sulphide of which the manganese sulphide is the more common. The sulphide of iron is present when the sulphur is high and the manganese is low. The sulphide of iron is seldom present in commercial steels as the manganese is usually present in sufficient quantities to combine with all the sulphur present.

When present as iron sulphide the phenomena of "hot shortness" or brittleness when hot is produced. It causes the metal to crack, tear and check in the rolling or forging and heat treating. The iron sulphide is brittle at the forging heat because it is in the molten condition so that there is little cohesion between the crystalline grains causing them to rupture when stressed in the working. The iron sulphide spreads out in thin sheets between the grains thus causing dangerous zones of weakness when cold. Also fine cracks may be formed in the rolling which are imperceptible in the finished product but which are very dangerous in service.

Manganese sulphide usually segregates in the form of globules or drops and is not as dangerous as the iron compound. These drops are drawn out in the rolling into long fine lines. Manganese sulphide often segregates with phosphides or slag to form ghosts in which condition it is very detrimental to the quality of the steel, the ghosts being zones or lines of weakness. Manganese sulphide is plastic at forging or rolling temperatures and does not interfere with the working of the metal as does the iron sulphide. It has been found that properly made steels with as high as 0.50 per cent sulphur with 1.06 per cent manganese could be forged easily and that

in the direction of rolling the mechanical properties were not affected and the impact resistance was even greater than the low sulphur steels. Transversely the high sulphur steel was weaker. Ship and boiler plates are known to be weaker transversely when high sulphur than the lower sulphur steels.

The higher the sulphur the greater the susceptibility of the steel to corrosion as the sulphides readily oxidize into oxides and sulphuric acid with consequent increase in the corrosion. It is important to have a sufficient amount of manganese present in the steel to insure that all the sulphur is combined with the manganese. Further care must be taken, however, as the sulphur is liable to segregate with the formation of iron sulphide with its attending dangers. Hence, the necessity for requiring a low sulphur analysis.

In slowly cooled steel castings iron sulphide often segregates to the crystalline boundaries forming basis upon which the ferrite crystals grow, producing a weakened structure. This condition may be largely broken up by annealing above the critical range. Most structural steels permit sulphur up to 0.06 per cent when sufficient manganese is present. For the better grades of steel for tools, etc., the sulphur should be below 0.04 per cent due to the danger of segregation. Excessive sulphur 0.12 per cent, produces a fibrous structure and a free cutting steel.

Detection of sulphur inclusions may be made by polishing the specimen and spreading over the surface a piece of silk which has been dipped in a solution of hydrochloric acid and mercuric chloride and holding for about five minutes. The sulphur is attacked by the acid forming hydrogen sulphide which deposits on the silk as black sulphide of mercury. The degree of color and size of the deposits indicate the segregation of the sulphur. Photographic silver bromide paper will show the same results first dipped in sulphuric acid. Under the miscroscope iron sulphide is a pale yellow or yellowish brown while manganese sulphide is a dull grey or dove color. Deep etching may show the amount of segregation by the size and location of the pits.

RELATIVE ECONOMY OF OIL, GAS, COAL AND ELECTRIC HEATED FURNACES

By Seth A. Moulton* and W. H. Lyman**

(A Paper Presented by Title at Philadelphia Convention)

It would seem as if no more important subject, than that of fuel economy could be discussed at this meeting. America's crippled railroads are unable to provide adequate transportation for fuels. The prodigality of past generations has in a large measure exhausted, or seriously depleted, the natural gas supply in those sections of the country where this commodity has been discovered. Owing to the demands of labor, the lack of adequate car facilities and the general increase in the cost of operating industrial enterprises the cost of coal has soared so rapidly that the consumer is paying not less than double, ofttimes treble and sometimes four times the price which he paid in 1914. Most serious of all, the demand for gasoline, kerosene and fuel oil has so far outstripped the rate of oil production that the price of fuel oil has reached a point where its use is almost prohibitive. Even if a con-

*Industrial Furnace Corp., Boston.
**General Superintendent, Warner Gear Co., Muncie, Ind.

sumer could afford to pay the highest price for fuel oil, there is a grave question as to how long he would be certain of a supply, as the demand is fast approaching and will soon overlap the visible supply.

The average consumer has been astounded and angered at the attack made on his purse by the advance in all commodities and particularly by the enormous increase in the cost of fuel, which is the most essential commodity. The consumer is disposed to place the blame for the costs, which appear to him so excessive, upon everything but the true cause. The war was at first to blame, then the railroads came in for their share of denouncement; "profiteers" is a favorite word to apply when no other specific point of attack appears and there is always the labor situation as an excuse. The law of supply and demand seems to be lost sight of entirely, for upon careful analysis of the problem, it will be found that the ultimate consumer's demand is the major factor that regulates costs. There have been a few unheeded voices raised in the wilderness during the past decade that have prophesied the stringency which we are now facing. These expert engineers were, when listened to, branded as calamity howlers; for why should the consumer be disturbed, or worry, with $3.00 coal, 3-cent oil, 12-cent kerosene, and 18-cent gasoline?

For years European industrial experts and engineers have been astounded at America's waste. Abundant natural wealth, intensive quantity production with a home market that consumed the output of its factories have been America's salvation in the past. But, prior to 1914, the manufacturers had commenced to feel the pressure of European competition and when the reconstruction period has reached a stage of stabilization, America's markets will be invaded as never before and the American manufacturer will be passing through an era which may prove disastrous if he does not prepare now for the emergency. Waste must be reduced to a minimum and there is no other item where more lucrative economy can be attained than by fuel or heat conservation. This statement especially applies to the present average industrial furnace practice, meaning by the term "industrial furnace," those furnaces in which heat is directly utilized for process work in contradistinction to those furnaces in which heat is utilized to generate power.

Owing to the vast scope of the industrial furnace field, it is necessary to confine this paper to a concrete case covering some particular industry. The case selected is the one with which the writers are most intimately familiar and probably one which will have special interest to a large percentage of the audience. The principles involved will apply to a large majority of the industries where quantities of small parts are heat treated.

The premises are as follows: A factory produces per day of 24 hours about 30,000 pounds of gears. The gear blanks are delivered to the factory directly from the hammers in the forge shop. The gears consist of the usual transmission and differential gears, such as used in automobiles. The transmission gears are high carbon steel and the differential low-carbon carburized. The necessary heat treating equipment will consist of:

1. Annealing Furnaces .... 1400-1600 degrees Fahr.
2. Carburizing Furnaces .... 1700-1800 degrees Fahr.
3. Hardening Furnaces .... 1450-1550 degrees Fahr.
4. Drawing Furnaces .... 350- 650 degrees Fahr.

All of the forging blanks are annealed before machining; about three-quarters of the machined gears and parts are carburized, all the carburized gears are given a double hardening for core and case, all gears and parts are hardened and all parts are drawn.

The possible sources of heat supply and their values are as follows:

1. Oil .... 140,000 b.t.u. per gallon
2. Natural Gas .... 1,100 b.t.u. per cubic foot
3. City Gas .... 650 b.t.u. per cubic foot
4. Water Gas .... 300 b.t.u. per cubic foot
5. Producer Gas .... 170 b.t.u. per cubic foot
6. Coal .... 12,000 per b.t.u. pound
7. Electric Current .... 3,412 b.t.u. per kilowatt hour

For the heat treatment previously specified only comparatively low temperatures are required. No difficulty will be experienced in attaining the desired maximum temperature of 1800 degrees Fahr. with any of the heating mediums above enumerated; but it should be noted that the producer gas with a b.t.u. of 170 per cubic foot and the electric current would require specially designed furnaces to obtain higher temperatures than 1800 degrees Fahr. The reason for this condition will be explained later.

As the economical utilization of the heat depends entirely upon the furnace design, it is necessary to describe the several types of equipment that are commercially available. Before describing the furnace designs and establishing their comparative merits, however, certain fundamental features that must be recognized in designing furnaces for any particular service should be enumerated.

The first factor to be taken into account is the probable flame temperature, or in other words the temperature of combustion that is to be derived from the burning of the fuel in a fuel-heated furnace. The second factor is the temperature required in the furnace working chamber. The third factor is the character and volume of material treated. The fourth factor is the cycle of the heating.

With the foregoing premises established, it is a comparatively simple matter to decide upon the general character of furnace design which will prove most economical in overall operating costs with a fuel at a given price.

Some criticism may be raised as to why the flame temperature is first recognized. There are important reasons for this course of procedure. The first reason is that we must ascertain whether or not the fuel or fuels under consideration can be made to yield the desired temperature. The second reason is that the maximum temperature which may be attained from a given fuel may be excessive and provisions then must be made to reduce this temperature, or provision must be made in the design of the furnace to withstand the excessively high temperatures.

After the first and second factors have been established, the important element affecting the general furnace design may be ascertained and this is the amount of heat which can be utilized effectively in the working chamber, taking into account the flame temperature and the temperature of the exhaust gases.

We will take as an example the specific case of a carburizing furnace having a working chamber temperature of 1800 degrees Fahr. heated with either oil, gas or coal fuel, with a heat cycle of eight hours

and a charge of 3000 pounds and of such dimensions that a working chamber 4 feet wide, x 6 feet long and 3 feet high is required.

The temperature of the exhaust gases at the outlet ports of the working chamber would be about 1900 degrees Fahr. This does not mean that there is an excessive temperature at the exhaust ports, but to allow for the losses through the walls of the furnace and maintain an interior temperature of 1800 degrees Fahr., the gases must be in excess of this temperature.

The theoretical flame temperature, or the combustion temperature, of oil with a theoretical air supply is about 5000 degrees Fahr. With this fuel we are immediately confronted with the problem of how we can overcome the destructive effects of this intense heat if the oil can be burned with theoretical efficiency? No refractory made will long withstand such a temperature and the best grade of ordinary firebrick would melt, especially under a load, at a much lower point. It is difficult to maintain furnace brickwork, particularly roof arches at temperatures in excess of 2500 degrees Fahr., but by proper distribution of the burners and with properly designed combustion chambers, it is possible to operate with oil flame temperatures around 3500 degrees Fahr. This means the admission of an excess air volume of 50 per cent more than the theoretical, if all of the carbon in the fuel is consumed. The generation of a smoky flame indicates that all the carbon is not consumed, and as the majority of oil-fired furnaces are so operated, it is quite likely that about 33 per cent excess air is used; or what is more likely if the burner discharges into a restricted area, the flame temperature is much below 3500 degrees Fahr., and usually more than twice the theoretical amount of air is admitted, reducing the combustion temperature to around 2500 degrees Fahr.

Assuming that the combustion chamber, the atomizing and the air mixing devices, or in other words the complete burner, is designed for securing a flame temperature of 3300 degrees Fahr. with a waste gas temperature of 1900 degrees Fahr., the approximate amount of heat wasted necessarily in the spent gases would be 1900/3300=0.57, leaving about 45 per cent of the heat generated available for useful work in the furnace chamber to be distributed in radiation through the furnace walls.

The heat required to bring the charge up to temperature will be approximately 3000 x 1800 x 0.17=918,000 b.t.u. and the heat lost through the walls of a properly constructed furnace of the dimensions given as indicated by tests will be 140,000 b.t.u. per hour, or for eight hours 1,120,000 b.t.u. This makes the total heat requirements in the chamber 2,038,000 b.t.u., but as only 43 per cent of the heat admitted in the fuel is available in the chamber, the amount of heat which must be admitted will be approximately 2,038,000/0.43=4,740,000 b.t.u. The amount of oil required per charge will then be 4,740,000/140,000=34 gallons. These figures are the very best results which we could expect to obtain in the commercial operation of an oil-fired carburizing furnace for the above-described service.

There can be no real comparison between the efficiency of furnaces employed on carburizing work and those used for heating only. Nevertheless, to demonstrate the important bearing which the character of the charge and the heat cycle has on furnace efficiency, we will assume that the furnace described is loaded with a charge of cast iron weigh-

ing 3000 pounds, so disposed that the heat can readily reach the entire charge and with the cross section of the pieces to be treated such that the full temperature of 1800 degrees Fahr. will be obtained in two hours.

The total heat required will then be 918,000 b.t.u. plus 2 x 140,000 b.t.u.=1,190,000/0.43=2,786,000 b.t.u. The fuel oil required will be 2,786,000/140,000=20 gallons. The relative efficiency of the furnace under the two cases will be as follows:

For carburizing 918/4,740 x 100=19.4 per cent.
For heating 918/2,786 x 100=33 per cent.

The preceding efficiencies never could be obtained in the ordinary commercial oil-fired furnace and probably could not be consistently maintained in a furnace of special design. The reasons are as follows: In our computations we have made no allowance for incomplete combustion and furthermore we have made no allowance for the heat lost in gasifying the fuel mist that is delivered at the burners or the heat value lost in the water vapor generated by combustion.

Reducing our flame temperatures to the practical work limits or from 2500 to 2700 degrees Fahr. the respective efficiencies for the two classes of service will be as follows:

For carburizing—2,038,000/(700-2500)=7,280,000 b.t.u.
Oil consumption=(7280-4740) x 34=52 gallons per charge.
Efficiency=100 (918,000-7,280,000)=12.6 per cent.
For heating—1,198,000/(700-2500)=4,280,000 b.t.u.
Oil consumption=4280/2786 x 20=30.8 gallons per charge.
Efficiency=100 (918/4280)=21.4 per cent.

Even these results are higher than would obtain under ordinary conditions because we have kept the furnace radiation losses at a low rate which could not be realized with a standard type of furnace. No allowance has been made for the heat lost in gasifying and in water vapor.

Numerous tests indicate that the usual oil-fired equipment used on the classes of service cited above have for carburizing an efficiency of about 5 per cent and for annealing from 10 to 15 per cent. Making due allowances for the losses from door openings and the almost certainty of improper combustion, the last cited figures can be relied upon as representing the best average practice.

It will be interesting for a few moments to analyze the above problems for the purpose of determining whether or not there can be made any material gain in economy. The heat distribution sums up as follows:

Carburizing—1st Case		
Entering work	918,000 b.t.u.	19.4 per cent
Loss from Walls	1,120,000 b.t.u.	23.6 per cent
Loss from waste gases	2,702,000 b.t.u.	57 per cent
Total	4,740,000 b.t.u.	100 per cent
Annealing—1st Case		
Entering work	918,000 b.t.u.	33 per cent
Loss from walls	280,000 b.t.u.	10 per cent
Loss from waste gases	1,588,000 b.t.u.	57 per cent
Total	2,786,000 b.t.u.	100 per cent

It is not necessary to review the second cases, which are closer to normal operating conditions, for the above are sufficient to indicate that the point where the greatest savings can be made is the utilizing the heat wasted in the flue gases. A very large percentage of the heat can be reclaimed by recuperation and returned as hot air to the furnace. But what will be the effect? The temperature of the flame will be increased and as we are already carrying that temperature up to, if not beyond the practical limits, there would be no appreciable gain from recuperation and the expense of such an installation is not justified. The only solution of the problem would be to burn the oil at nearer its theoretical temperature by reducing the volume of air and constructing a combustion chamber, outside the limits of the working chamber, which could resist the high flame temperature. Up to the present date this has not been satisfactorily accomplished, although numerous attempts have been made. We are, therefore, confronted with the inherent fault in oil fuel for furnace service which precludes its efficient use and consequently its economical use when a high price must be paid for the heat content in the oil that must be wasted.

As it is impractical to provide means which will make any material saving in the waste gas losses, the next and only means whereby a saving may be made is in the radiation losses. It has already been stated that the hypothetical furnace was provided with extra heavy insulation. By adding an extra 4-inch thick course of insulating brick the radiation losses can be reduced by about two-fifths. Hence, the total heat consumption can be reduced by about 16.7 per cent when the furnace is used for carburizing and about 7.1 per cent when the furnace is used for heating. The cost for the extra insulation will be approximately $1000 taking all factors into account. For furnace work we are justified in capitalizing an investment at 25 per cent allowing 15 per cent for fixed charges and maintenance and 10 per cent for apparent net profit. It follows that there must be a saving of 250 per year to justify the additional insulation cost. Assuming that the furnace is operated continuously for 300 days of 24 hours per day, the oil saving would be 3 charges x 34 gallons x 300 days x 16.7 per cent=5110 gallons=4.9 cents per gallon or more. We would be justified in incurring the extra insulation expense, if the furnace was to be used continuously for carburizing. With the furnaces used for heating, a saving of 5110 gallons of oil could be made under continuous operation, which checks the preceding figure.

The preceding discussion on the insulation savings brings out an important point which should be noted and this is that the heat cycle and character of the load combined with the hours of service per day have an important influence on the determination of the furnace design. The fallacy of attempting to utilize a stock pattern furnace for a diversified service without carefully analyzing its suitablity for the contemplated service is also self evident.

Without setting forth the detailed calculations; but proceeding upon the same basis of analysis as previously described and confining our conclusions to Case 2 as representing the best attainable practice, the following tabulation gives the fuel consumption and the efficiency of the four different classes of gas fuels.

Only one factor requires discussion in order that the efficiencies given in the tabulation may be understood. This is the factor that gas may be

more efficiently burned than solid fuels, either oil or coal. This is possible for two reasons: First, the flame temperatures for the complete combustion of gases are lower than for oil or coal; and second, that gas may be burned with approximately the theoretical volume of air required for complete combustion. By calculating the products of combustion, and by comparative tests, it can be shown that under commercial operating conditions producer gas is 15 per cent more efficient than oil, blue gas 30 per cent more efficient, city gas 35 per cent more efficient, and natural gas 50 per cent more efficient for furnace service at the temperatures under consideration.

The gas fuel consumption and the efficiencies for carburizing will then be as follows:

Producer gas	37.3 M cubic feet per charge	14.5 per cent
Blue Water Gas	18.7 M cubic feet per charge	16.4 per cent
City gas	8.3 M cubic feet per charge	17.0 per cent
Natural gas	4.4 M cubic feet per charge	18.8 per cent
For Heating		
Producer gas	22.0 M cubic feet per charge	24.6per cent
Blue water gas	11.1 M cubic feet per charge	27.6 per cent
City gas	4.9 M cubic feet per charge	28.8 per cent
Natural gas	2.6 M cubic feet per charge	32.0 per cent

The above efficiencies are admitted to be higher than would obtain in usual practice due to the heavy insulation conditions assumed as previously mentioned and also due to the fact that the load per square foot of hearth is the maximum that could be obtained under the most favorable conditions. A load of 2000 pounds would much more nearly represent average practice, but the high ratings herewith assumed were purposely selected to indicate the maximum limits of economy which might be secured.

To continue the comparison using coal as a fuel, it is necessary to modify our method of analysis because the design of coal-fired furnaces will be radically different from the oil or gas-fired. This necessary change in design will increase the radiation losses and there will also be losses in the ashes. Carrying out the computations with the above modifications yields results as follows:

Carburizing

Heat entering work	918,000 b.t.u.	8.4 per cent
Radiation losses	1,500,000 b.t.u.	13.7 per cent
Waste gas losses	2,418,000 b.t.u. $\frac{[2700-1900]}{2700}$	75.1 per cent
Ashes	320,000 b.t.u.	2.8 per cent
Total	10,968,000 b.t.u.	100 per cent

The amount of coal burned then will be 10,968,000/12,000=914 pounds per charge, or 3.3 pounds of charge heated per pound of coal.

Under actual working conditions the amount of gross charge treated per pound of coal from actual tests and records varies from 1.75 to 5 pounds, and for a heat cycle and load corresponding to the hypothetical case above cited, the actual test shows exactly the same production as that given by the above computations; 3.3 lbs. of metal per pound of coal.

For heating the following will apply:

Heat entering work	918,000 b.t.u.	15.75 per cent
Radiation losses	375,000 b.t.u.	6.45 per cent
Waste gas losses	4,370,000 b.t.u.	74.88 per cent
	1,293,000	
	800÷2700	
Ash losses	170,000 b.t.u.	2.92 per cent
Total	5,833,000 b.t.u.	100.00 per cent

The amount of coal required for heating only then is 5,833,000/12,000=486 pounds per charge or 6.2 pounds of metal per pound of coal. This result checks with actual tests and may be considered conservative.

An electric furnace of the metallic resister type might be employed for either the carburizing or the heating work. The economy of such a furnace would depend upon the cost of power.

As all of the losses from an electric furnace are by radiation, it follows that the use of extra heavy insulation is justified. Practice has demonstrated that for a furnace of the size under consideration, operating at 1800 degrees Fahr., the radiation losses will be not more than 30 kilowatts per hour. The heat and power requirements of such a furnace on carburizing will then be as follows:

Radiation losses 30K.W. x 8	240 k.w.hrs.@3412	b.t.u.	818,880 b.t.u.	47 per cent
	269 k.w.hrs.@3412	b.t.u.	918,000 b.t.u.	53 per cent
Total	509 k.w.hrs.	b.t.u.	1,736,880 b.t.u.	100 per cent

For heating

Radiation losses 30 x 2	60 k.w.hrs.@3412	204,720 b.t.u.	18.25 per cent
	269 k.w.hrs. 3412	918,00 b.t.u.	81.75 per cent
Total	329 k.w.hrs.	1,122,720 b.t.u.	100.00 per cent

We can compile a tabulation from the preceding computations which will show the relative value of the several types of furnaces and heating mediums. The rates which prevail in a central western district for the several heat services are as follows:

1. Oil ....50 cents per gallon
2. Natural gas ....50 cents per thousand cu. ft.
3. City gas ....80 cents per thousand cu. ft.
4. Water gas ....40 cents per thousand cu. ft.
5. Producer gas ....10 cents per thousand cu. ft.
6. Coal ....$6.00 per long ton
7. Electric current ....1⅛ cents per kilowatt hour

Applying the above values the accompanying Table I, comparative operating costs has been prepared. The results shown on this tabulation indicate that, with the exception of natural gas, clean producer gas and coal are by far the most economical fuels to employ and that electricity, under the premises assumed is not economical. Like all figures pertaining to furnaces, these conclusions should not be given a general application. In most instances, it will be found that producer gas and coal are much cheaper than oil unless

oil can be purchased for less than 8 cents per gallon, but in many cases it will be found that electricity can compete with almost any class of fuel if power can be purchased at a reasonable price and the service is such that the benefits derived from the highly efficient electric furnace can be utilized advantageously.

The hypothetical cases assume a character of loading which does not demand accurate temperature control. We have also assumed that the fixed charges for the electric furnaces would be the same as for the fuel-fired furnaces. This is not true as the electric furnace will have double the life of the fuel-heated. We have also assumed the labor element would be the same for the fuel furnaces, with the exception of coal, as for the electric. This is not true because if the high economy is to be secured particularly from oil-fired equipment, very skillful attention will be required and the cost for operating labor on the fuel-fired equipment will be much more than for the electric furnace.

TABLE I
Comparative Operating Costs

No.	Class Fuel	Fuel per charge	Fuel cost	Installation cost	Efficiency per cent	Operating costs: Fixed charges	Operating costs: Extra labor	Operating costs: Heat	Operating costs: Total per charge	Operating costs: Cost per pound	Saving over oil: per charge	Saving over oil: per cent
	CARBURIZING											
	1	2	3	4	5	6	7	8	9	10	11	12
1	Oil	52 gal	15c	$2400	12.6	$0.40	....	$7.80	$8.20	$0.00274	....	..
2	Natural gas	4.4 M	50c	2400	18.8	0.40	....	2.20	2.00	0.00087	5.60	68
3	City gas	8.3 M	80c	2400	17.0	0.40	....	6.64	7.04	0.00235	1.16	14
4	Water gas	18.7 M	40c	2400	16.4	0.40	....	7.48	7.88	0.00263	.32	3.9
5	Producer gas	37.3 M	10c	2400	14.5	0.40	....	3.73	4.13	0.00137	4.07	50
6	Coal	914 lb.	6.00	3600	8.4	0.60	$1.20	2.45	4.25	0.00140	3.95	48
7	Electricity	500 K.W.H.	1½c	9000	53	1.50	....	7.50	9.00	0.00300	0.80	9.7
	HEATING											
1	Oil	30.8 gals	15c	2400	21.4	0.10	....	4.62	4.72	0.00157	....	..
2	Natural gas	2.61 M	50c	2400	32.0	0.10	....	1.30	1.40	0.00047	3.32	70
3	City gas	4.9 M	80c	2400	28.8	0.10	....	3.92	4.02	0.00134	0.70	14.8
4	Water gas	11.1 M	40c	2400	27.6	0.10	....	4.44	4.54	0.00151	0.18	3.8
5	Producer gas	22.1 M	10c	2400	24.6	0.10	....	2.21	2.35	0.00078	2.37	50.3
6	Coal	486 lb.	6.00	3600	15.75	0.15	$0.30	1.30	1.75	0.00058	2.97	63
7	Electricity	329 K.W.H.	1½c	10500	81.75	0.44	....	4.94	5.38	0.00179	0.66	14

Cost of oil and gas-fired furnaces installed $100 per square foot of hearth
" " coal-fired furnace installed 150 " " "
" " electric furnace 100 kilowatt capacity installed $90 per kilowatt
" " " " 150 " " " 70 " "
Output 3000 pounds charge—8 hours heating and carburizing, 2 hours heating only
Fixed charges including interest, depreciation, taxes, insurance and maintenance 15 percent
Extra operating labor for coal-fired furnace 60 cents per hour, one man 4 furnaces
Annual service 7200 hours

There is another very important feature in connection with the installation of electric furnaces that must be taken into account and this is the increased load and higher power factor occasioned by the furnace load. To illustrate: Suppose a factory having electric furnaces of the character considered in the tabulation, has an average load of 100 kilowatts for 20 hours, or a power consumption of 2000 kilowatt hours per day and that the rate for this power is 2 cents per kilowatt hour or a total of $40 per day. Assuming that two furnace units are required for carburizing, the heating power will be 3 x 2 x 500=3000 kilowatt hours per day. The addition of this power under the average system of rate scheduling should reduce the cost for all the power to 1½ cents per kilowatt, making a saving of $10 per day which should be deducted from the furnace power. With the charges per day as have been assumed in all the preceding computations, there will

be a saving per furnace charge of $10/(3 x 2)=$1.67. Subtracting this amount from the cost in Table I of $9.00 for electric carburizing makes the cost $7.33, showing a saving of 77 cents per charge, or a gain of 9½ per cent by the use of electric furnaces.

When complete heat treating plants are electrified, or when large furnace units of the resistor type are installed in connection with an industry of average character, usually it will be found that the saving in the mill power cost will justify electric furnace equipment.

The authors do not purport to claim that the accompanying methods of determining furnace economy are scientifically accurate, because they fully appreciate that the chemical composition of the fuel and the escaping gases must be analyzed to solve with minute accuracy the actual furnace efficiency; but the results as derived by the methods employed are found to check with actual tests and they are accordingly sufficiently accurate for all practical purposes.

Applying the general methods of deduction which have been employed in the general discussion which precedes to the specific case of a gear plant producing 30,000 pounds per day of 24 hours with specifications as cited at the introduction of this paper, we must first select the possible combination of equipment that may be employed.

For annealing forgings that will produce 30,000 pounds of finished gears about 40,000 pounds of blanks must be treated. Two methods may be employed for annealing. First, the blanks may be placed loose upon the furnace hearth and second, the blanks may be packed in boxes. In the first case, the blanks will be allowed to cool in the furnace and in the second case the loaded boxes will be transferred to a cooling chamber. The second system is far superior to the first on account of the fact that the furnace working chamber will be kept up to temperature and the blanks being packed in boxes and cooled in a chamber free from circulating air will be cooled more uniformly and with less scale. Thus economy of fuel and high quality of product will be obtained. The heat cycle for this class of work is usually from 6 to 8 hours up to the temperatures of 1550 degrees Fahr. the material being left in the cooling chamber for approximately the same time as it is retained in the furnace. If no cooling chambers are used, the material is usually allowed to cool in the furnace to 600 to 800 degrees Fahr. or from 2 to 4 hours.

As a slow anneal appears to produce more satisfactory results, we will employ a heat cycle bringing to heat in 8 hours, cooling in air 3 hours, and in chambers 8 hours.

Actual practice has demonstrated that the weight of boxes to charge for annealing work is from 25 to 30 per cent and that loaded boxes, resting upon special rail and ball races and weighing about 2100 pounds can be handled conveniently. With 28 per cent of the weight tare, the net weight per box will be 1500 pounds. For 40,000 pounds per day, about 27 boxes will be required, or for an 8 hour heat cycle, 216 box hours. An economical size of furnace to handle these boxes will have a hearth about 4 feet wide x 7 feet 6 inches deep and 3 boxes can be accommodated per charge. A furnace of this size will handle 9 boxes per day, hence 3 chambers will be required for heating and three for cooling. These 3 working chambers can be built in a single battery or two batteries of two working chambers each may be employed leaving one chamber as spare.

With the heat cycle specified and with coal-fired furnaces of the di-

mensions described, the actual fuel consumption in commercial operation has an average of about 20 pounds of metal gross, or about 14 pounds of metal net per pound of coal having a heat value of 14,000 b.t.u. per pound. Such furnaces then show a commercial efficiency of approximately $[(20 \times .17 \times 1550)/14{,}000] \times 100 = 37.6$ per cent gross, of 27 per cent net. Reverting to the Table I under line 6, column 5, for coal fired heating it will be observed that for the 2-hour cycle heating only without cooling that the efficiency is only 15.75 per cent. If the cooling were accomplished in the working chamber this efficiency would drop to less than 12 per cent net. Again referring to Table I, line 6, column 10, the price per pound for heating is 0.058 cent, which will be increased by cooling to not less than 0.075 cent.

There would be required at least six chambers 4 x 6 feet to anneal and cool the work in the working chambers. These would cost, as shown in Column 4, Table I, 3600 x 6=$21,600. The two twin-chamber units with cooling chambers would cost $13,500 each or $27,000, making an increased investment of $5400. The annual saving with cooling chambers would be 0.075 cent—0.058 cent x 40,000 pounds x 300 days=$3240 per year. Hence the investment value would be $3240/$5400=60 per cent. Taking into account the cost for annealing boxes and their depreciation, it is safe to state that the cooling chamber type of furnace would pay for itself in two years.

It is a simple matter to ascertain what the relative economy would be approximately with the other types of fuels by using the comparative efficiencies given in Table I.

For carburizing units to treat 75 per cent of 30,000 pounds, or 22,500 pounds of gears per day, if the gears are packed in cast alloy steel boxes with the net weight of the material treated about 33 per cent of the gross weight of the charge, there will be required eight chambers about 4 feet x 7 feet 6 inches. The above ratio of net to gross charge corresponds with good average practice. If high grade and expensive alloy boxes are employed it is possible to make the net weight about 50 per cent of the gross, but for the purpose of this paper the more usual conditions have been assumed.

Any of the heating mediums may be used in connection with the carburizing units. Under normal service it is not to be expected that the high efficiencies shown in column 5, Table I will obtain. From actual tests on well designed and operated equipment it has been found that 10 per cent efficiency represents about the best results that may be expected for carburizing work requiring a heat cycle of from 8 to 10 hours. In the comparative statements which follow later 10 per cent is the efficiency which has been employed for oil fuel prorated for the relative efficiency of the other classes of heating elements.

Several methods may be employed for hardening as follows:

1. Lead pots, oil or gas-fired.
2. Plain box type furnaces, lot charged,
   Oil or gas-fired or electrically heated.
3. Continuous furnaces, gas or electric heated.

It will probably be noted quickly that coal has not been considered as a possible fuel for the hardening furnaces. Coal-fired furnaces are undoubtedly the most economical type that can be employed, except when

an abundant supply of natural gas is available at a reasonable cost, but it is not a fuel that can be used efficiently on short heat service when accurate temperature control is essential. For annealing, carburizing, or any work requiring long soaking heat, especially when the size of the installation and the correlated service demands do not justify the expense of a gas producer installation, coal should always be given serious consideration.

It will also be noted that electricity has not been considered as a possible heating medium for the lead pots. This is due to the fact that the metallic resistor type of furnaces is the only one which has yet been developed to a point of certain economic application for heat treating work. This fact, combined with the limits of temperature, 1900 degrees Fahr. at which the metallic resistors may be operated, preclude the use of the electric-heated lead pots, on account of the transmission drop between the temperatures of the heating elements and the lead bath. At least 500 degrees Fahr. should be allowed for this drop, which means that the lead bath could not be maintained at a higher temperature than 1400 degrees Fahr. If heavy charges are immersed in the lead it is more than probable that even 1400 degrees Fahr. could not be maintained uniformly. At the present state of the art this is too close a working margin, thus conservative engineering necessitates disregarding electric heat for pot hardening. This subject should not be summarily dismissed without mentioning the fact that designs are now being prepared and tests are soon to be carried out on a new form of electric heated pot hardening furnace. The results of these tests may reverse the conclusions above set forth.

One more fact may be noted which is that oil has not been included as a heating medium for continuous furnaces. The manufacturers and advocates of oil fired equipment we are sure will take exception to this omission, but if the problem is surveyed from an unbiased viewpoint we feel certain that our conclusion in this respect will be sustained. The contention will be made that there are a great number of oil fired continuous furnaces operating successfully. Admitting this statement, let us consider how successful such installations may be and especially the class of service where they have been, or are being, used with economy.

For heavy billet and ingot heating, for large shells and gun rings, or in fact, where a large mass of metal in any form is constantly within the working chamber of the furnace any fuel that will afford the required temperature may be employed successfully. But even for heavy coarse work of this character when temperatures above 1800 degrees Fahr. are required, it will be found that gas will give much better results and be more susceptible of accurate control, as well as more efficiently burned than oil. When continuous furnaces are utilized for small parts requiring accurate temperature control the regulation of an oil-fired continuous furnace is a formidable problem and, except in special isolated instances, it will be found that accurate control cannot be maintained even by the most skilled operators. Automatic control devices have not yet been devised for oil firing which will operate continuously and uniformly. With gas and electricity absolute control may be maintained automatically although continuous gas furnaces must be watched with closer attention than electric furnaces.

The subject of continuous furnaces covers a field of such scope that it is impossible to attempt even a brief synopsis of it in this paper. However,

a word of warning should be inserted at this time, for it is our firm belief that continuous furnaces have been used in many cases where they were not justified by the overall economy secured. Continuous furnaces must be selected and adopted for a particular service only after careful study.

We have no brief against oil fuel and we are accordingly not attempting to condemn this wonderful gift of nature that is such a potent factor in our modern life. Nevertheless, it must be conceded that the rapid adoption of fuel oil for furnace work was occasioned by the cheapness of this commodity prior to 1914, coupled with the low first cost of oil furnaces and the auxiliary equipment required.

Another feature should be mentioned before passing from the general discussion of the hardening furnaces. We refer to the use of lead pots. Scale is, of course, prevented and a uniform product is assured; but as against these advantages, the parts treated must be immersed in salt or some other solution to prevent the adhesion of the lead and even such precautions do not eliminate the necessity for cleaning the gears after treatment. The efficiency of lead pots rarely ever equals 5 per cent and almost never exceeds this point in continuous or overall efficiency.

For the particular service under consideration approximately 80 per cent of the carburized material will be ring gears, or about 17,000 pounds. It is impractical if not impossible to utilize a quenching machine for these gears when they are heated in a lead bath, and as they are bound to become more or less distorted, either when being hardened or quenched or as the combined result of both causes, it follows that extra expense must be incurred for straightening after hardening.

With an electric or an oil or gas-heated furnace, properly fired, it is possible to keep the scaling at such a low amount that it will not be detrimental. This is especially true of the electric gas furnaces. With an oil furnace it is probable that sand blasting may be necessary and even with a gas or electric furnace, light sand blasting may be needed to produce perfect work.

While the use of lead pots may be warranted for particular grades of work, we do not believe that they are a necessity for gear plants such as we are considering in view of the advancements which have been made in both the gas and electric furnace design and operation. Neither do we believe that they are economically sound for this particular service.

Either oil bath, or lead pots, oil, gas, or electric heated gas, heated semimuffle type, or electric heated semimuffle type furnaces may be used for drawing. For the low temperatures required, experience has proven conclusively that the electric furnace is the best equipment for this service. The oil bath is highly satisfactory but it is a messy proposition compared with the electric furnace. Gas furnaces for such low temperatures are controlled with difficulty and cannot be advocated for temperatures below 900 degrees Fahr. The lead pot has the disadvantages previously described under hardening furnaces.

We are now in a position to consider the possible combinations of equipment and heating mediums that may be employed and to ascertain the most economical installation for a complete plant under the assumed premises as to the cost of heating, mediums, the material to be treated, and the character of the heat treatment.

For convenience in presentation we have subdivided the possible grouping into cases as follows:

Case I. All oil-fired	Cost
Efficiency for annealing 30 per cent—carburizing 8 per cent, hardening 14 per cent and drawing 4 per cent.	
(a) Annealing (40,000 pounds net or 51,200 pounds gross), two twin chamber units with cooling chambers, hearth 4 feet x 7 feet 6 inches	$ 22,000.00
(b) Carburizing (22,500 pounds net of 67,500 pounds gross) 8-units, hearth 4 feet x 7 feet 6 inches....	24,000.00
(c) Hardening (52,500 pounds net) average charge 100 pounds—24 per 22 units, hearth 3 feet x 4 feet day= 3600 pounds per year	28,000.00
(d) Drawing (22,500 pounds net—Average Temp.—950 degrees Fahr.), (7500 pounds net average Temp. 450 degrees Fahr.), 10 lead pots	30,000.00
2 oil bath furnaces	3,000.00
(e) Storage and complete oil system, 90,000-gallon tank, pumps, blowers, steamp piping, oil piping, etc.....	72,000.00
Total furnace equipment cost	$179,000.00
Fuel consumption 1,040,000 gallons per year @ 15c	$156,000.00
Labor—on basis 60 pounds metal per man hour= (30,000/60) x 300 days @ 75c per hour ......=	105,000.00
Fixed charges 15 per cent of $179,000	26,850.00
Total annual operating cost exclusive of carburizing compound, pots, inspection, and fixed charges on buildings and land	$287,850.00
Cost per pound $0.0319	

Case II. Oil-fired annealing and carburizing, electric hardening and drawing. Efficiency oil same as Case I—Efficiency electric hardening 60 per cent, electric drawing 70 per cent.	
(a) Annealing—same as Case I	$ 22,000.00
(b) Carburizing—Same as Case I	24,000.00
(c) Hardening—6 18-inch hearth rotary electric furnaces complete installed	90,000.00
(d) Drawing—4 30-inch diameter cylindrical drawing furnaces, complete	24,000.00
(e) Transformers—wiring and main switchboard equipment for 600 kilowatts	15,000.00
(f) Oil storage and distribution system	38,000.00
Total cost of furnace and equipment	$213,000.00
Oil consumption 643,000 gallons per year @ 15c..	$ 96,950.00
Electric current consumption 3,088,000 kilowatt-hours per heat @ $1\frac{1}{2}$c	46,320.00
Labor on basis 65 pounds metal per man hour	97,000.00

Fixed charges 15 per cent $213,000	31,950.00
Total annual operating cost	$272,220.00

Cost per pound $0.0302

Saving over oil 15,630 or 46 per cent on the incurred investment of $34,000. Note that this saving is made without crediting the oil electric installation with the reduction in the power rates occasioned by the increased load factor imposed by the electric furnaces.

Case III. All natural gas fired. Efficiency anneal 45 per cent, carburizing 12 per cent, hardening 21 per cent, drawing 6 per cent.

Equipment (a) to (d) same as Case I	$107,000.00
Piping mains	10,000.00
Total furnace equipment cost	$117,000.00
Fuel 88,500 M cubic feet gas @ 50c	44,250.00
Labor 65 pounds metal per man hour	97,000.00
Fixed charges 15 per cent of $117,000	17,550.00
Total annual operating expense	$158,800.00

Cost per pound $0.0178

Case III (A) Same as Case III but displacing lead pots with continuous gas drawing furnaces.

Total furnace equipment cost with piping	$120,000.00
Fuel cost 82,000 M cubic feet per year @ 50c	41,000.00
Labor 67 pounds metal per man hour	94,000.00
Fixed charges 15 per cent of $120,000	18,000.00
Total annual operating expense	$153,000.00

Cost per pound $0.017

Case IV. Natural gas annealing and carburizing, electric hardening and drawing.

Equipment (a) and (b) same as Case I	$ 46,000.00
Equipment (c) (d) and (e) same as Case II	129,000.00
Piping mains	6,000.00
Total furnace equipment cost	$181,000.00
Gas consumption 55,000 M cubic feet per year @ 50c	27,500.00
Electric current consumption same as Case II	46,320.00
Labor 70 pounds metal per man hour	90,000.00
Fixed charges 15 per cent $181,000	27,150.00
Total annual operating expense	$190,970.00

Cost per pound $0.0213

Case V. All city gas

Efficiency Annealing 40.5 per cent Carburizing, Hardening, Drawing 13.5 per cent

Equipment (a) to (d) same as Case III (A)	$120,000.00
Piping mains	2,000.00
Total cost of furnace equipment	$122,000.00

Gas consumption 169,800 M. cubic feet @ 80c......$133,200.00
Labor 67 pounds metal per man hour................ 94,000.00
Fixed charges 15 per cent of $122,000............... 18,300.00

Total annual operating expense..................$245,500.00
Cost per pound $0.0272

Case VI. City gas annealing and carburizing, Electric hardening and drawing
Equipment (a) and (b) same as Case III..........$ 46,000.00
Piping mains 7,000.00
Equipment (c) and (e) same as Case II............ 129,000.00

Total cost of furnace equipment................$182,000.00

Gas consumption 103,000 M. cubic feet per year @ 80c$ 82,400.00
Labor 70 pounds metal per man hour................ 90,000.00
Fixed charges 15 per cent of $182,000.............. 27,300.00

Total annual operating expense..................$246,020.00
Cost per pound $0.0274

Case VII. All water gas
Efficiency annealing 39 per cent Carbonizing 10.5 per cent, Drawing 13.5 per cent
Equipment (a) to (d) same as Case III (A)........$120,000.00
Piping mains 4,000.00

Total cost for furnace equipment................$124,000.00
Water gas plant complete..................... 90,000.00

Total investment $214,000.00
Gas consumption 375,000 M. cubic feet per year @ 30c $112,500.00
Labor 67 pounds per man hour...................... 9,400.00
Fixed charges 15 per cent of $124,000.............. 18,800.00

Total annual operating expense..................$225,300.00
Cost per pound $0.025

Saving over oil Case I, $67,250 annually on an incurred investment of $25,000

Case VIII. Water gas Annealing and carburizing, Electric Hardening and drawing
Equipment (a) and (b) same as Case I............$ 46,000.00
Equipment (c) (d) and (e) same as Case II........ 129,000.00
Gas piping mains................................ 8,000.00

Total cost for furnace equipment................$183,000.00
Water gas plant.................................. 55,000.00

Total investment $238,000.00
Gas consumption 237,000.00 M. cubic feet per year @ 30c ....$ 71,100.00

Electric current same as Case II	46,320.00
Labor same as Case VI	90,000.00
Fixed charges 15 per cent $183,000	29,950.00
Total operating expense	$235,370.00
Cost per pound $0.0262	

Case IX. All producer gas

Efficiency. Annealing 34.5 per cent, carburizing 9.3 per cent hardening 16 per cent drawing 11.5 per cent

Equipment cost (a) to (d) same as Case III (A)	$120,000.00
Extra for piping mains	6,000.00
Total cost of furnace equipment	$126,000.00
Cold clean producer plant complete	120,000.00
Total Investment	$246,000.00
Gas consumption 746,100 M. cubic feet per year @ 10c	$ 74,610.00
Labor same as Case VII	90,000.00
Fixed charges 15 per cent of $126,000	18,900.00
Annual operating expense	$183,510.00
Cost per pound $0.0204	

Saving over cost of oil, $104,340 per year or an incurred investment of $67,000 or 156 per cent return.

Case X. Producer gas annealing and carburizing, electric hardening and drawing

Equipment (a) and (b) same as Case III	$ 46,000.00
Piping mains	10,000.00
Equipment (c) (d) and (e) same as Case II	129,000.00
Total cost of furnace equipment	$185,000.00
Producer plant	70,000.00
Total investment	$255,000.00
Gas consumption 462,000 M. cubic feet per year @ 10c	$ 46,200.00
Electric current same as Cases II and VIII	46,320.00
Labor same as Cases VI and VIII	90,000.00
Fixed charges 15 per cent of $185,000	27,750.00
Total annual expense	$200,270.00
Cost per pound $0.0236	

Case XI. Coal annealing and carburizing, electric annealing and drawing

Efficiency annealing 30 per cent, carburizing 6 per cent, hardening 60 per cent, drawing 70 per cent

(a) Annealing

2-twin chamber units with cooling chambers	$ 27,000.00

(b) Carburizing	
4-twin chamber units	38,000.00
(c) (d) and (e) same as Case II	129,000.00
Total cost of furnace equipment	$194,000.00
Coal consumption 4300 tons per year @ $6.00	$ 25,800.00
Firemen labor 3 men per shift, 3 shifts, 9 men @ 70c or $2.10 per hr x 7200=	15,100.00
Electric current same as Case X	46,320.00
Labor 70 pounds metal per man hour	90,000.00
Fixed charges 15 per cent of $194,000	29,100.00
Total annual expense	$206,520.00
Cost per pound $0.023	

Saving over oil $171,530 per year on an investment of $15,000.

Case XII. All electric

Efficiency. Annealing 75 per cent, carburizing 40 per cent, hardening 60 per cent, drawing 70 per cent

(a) Annealing units	$ 33,000.00
(b) Carburizing units	60,000.00
(c) Hardening units	90,000.00
(e) Drawing units	24,000.00
(f) Transformers, wiring and switchboard	50,000.00
Total cost of furnace equipment	$257,000.00
Electric power cost 9,000,000 kilowatt hours per year @ 1½c	$135,000.00
Labor 75 pounds metal per man hour	84,000.00
Fixed charges 15 per cent of $257,000	38,550.00
Total annual expense	$257,550.00
Cost per pound $0.0286	

From Table II, Column 10, we can determine at a glance which system is the best to select from the viewpoint of overall economy under the premises which have been used in this paper for the cost of the respective heating mediums. As these costs are somewhat higher than the prevailing rates in most sections of the country at this time and as the relative values may be considered generally comparable for different sections of the country, Table II may be considered as typically representing the merits of the several systems.

Natural gas cannot be secured, and where it is available, the supply is rapidly diminishing and the cost advancing. As this fuel is localized it should be eliminated from our general discussion.

Eliminating natural gas places Case IX, all producer gas, as the best substitute for oil, with Case XI covering coal carburizing and annealing with electric hardening and drawing of almost equal merit with a much reduced initial investment. The great argument in favor of producer gas is that it can usually be applied to existing equipment and this equipment may be gradually replaced by more efficient furnaces from time to time as the occasion warrants.

It will be found in many cases that electric power for heating service is much cheaper than the 1½ cents per kilowatt-hour which we have used. Generally a price of somewhat under a cent per kilowatt-hour can be obtained. With a price of one cent, the all electric equipment, Case XII, shows an investment value of 29.4 per cent. In a number of instances power can be obtained for ½ cent per killowatt-hour and then Case XII shows an investment value of 65 per cent.

It is obvious that each plant must be analyzed taking into account all of the local conditions, but on general principles the following summary generally illustrates the demerits and merits of the several classes of heating mediums when used in furnaces of proper design.

OIL—ADVANTAGES

1. Low first cost for instaliation
2. Convenient fuel to handle
3. Simplicity of installation

DISADVANTAGES

1. High cost of fuel

TABLE II

Comparative Annual Production, Costs for 30,000 Pounds per 24 Hours

Case	Equipment	Installation cost	Annual operating expenses				Cost per pound metal cents	As compared with Case I	
			Fixed charges	Heat	Labor	Total		Annual saving	% on Investment
1	2	3	4	5	6	7	8	9	10
I	Oil	$179,000	$26,850	$156,000	$105,000	$287,850	3.19	....	....
II	Oil and electric	213,000	31,950	143,270	97,000	272,220	3.02	$ 15,630	7.35
III	Natural gas	117,000	17,550	44,250	97,000	158,800	1.78	129,050	110.00
III(A)	Natural gas continuous	120,000	18,000	41,000	94,000	153,000	1.70	134,850	113.00
IV	Natural gas and electric	181,000	27,150	73,820	90,000	190,970	2.13	96,880	53.50
V	City gas	122,000	18,300	133.200	94,000	245,500	2.72	42,350	34.60
VI	City gas and electric	182,000	27,300	128,720	90,000	246,020	2.74	41,830	23.00
VII	Water gas	214,000	18,800	112,500	94,000	225,300	2.50	62,550	29.20
VIII	Water gas and electric	237,370	27,950	117,420	90,000	235,370	2.62	52,480	22.20
IX	Producer gas	246,000	18,900	74,610	90,000	183,510	2.04	104,340	42.50
X	Producer gas and electric	255,000	27,750	92,520	90,000	210,270	2.36	77,580	30.40
XI	Coal and electric	194,000	29,100	87,220	90,000	206,320	2.30	81,530	42.00
XII	Electric	257,000	38,550	135,000	84,000	257,550	2.86	30,300	11.80

NOTE: Producer plant fixed charges are included in the cost of gas and are charged as heat in column 5, thus they are omitted from column 4.

2. Uncertainty of fuel supply
3. Difficulty of controlling temperature
4. Damage to product caused by No. 3
5. Inefficient combustion
6. Damage to furnaces from high temperatures when burned efficiently
7. Fire hazard
8. Continuous furnaces not practical except for large masses of metal
9. High labor cost due to Nos. 3, 5, 6, and 8
10. Short life of container boxes as compared with nonoxidizing gas fuel

Natural gas—especially valuable for high temperature work

ADVANTAGES

1. High heat value
2. Small pipe mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperature of combustion
5. Accurate temperature control
6. Uniform quality of product

7. Minimum damage to product
8. Simplicity of installation
9. Low cost of installation
10. Low fuel cost
11. Cleanliness of plant
12. Low fire risk
13. Low cost for upkeep due to Nos. 3 and 4
14. Low labor cost
15. Minimum scale

DISADVANTAGES

1. Unreliability of supply
2. Increasing cost due to No. 1

City gas—Especially adapted for high grade, high temperature work

ADVANTAGES

1. High heat value
2. Small pipe mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperature of combustion
5. Accurate temperature control
6. Uniform quality of product
7. Minimum damage to product
8. Simplicity of installation
9. Low cost of installation
10. Cleanliness of plant
11. Low fire risk
12. Continuous furnaces practical
13. Low maintenance
14. Low labor cost
15. Minimum scale

DISADVANTAGES

1. High fuel cost

Water-gas—Most valuable for high grade, high temperature work

ADVANTAGES

1. High heat value
2. Small piping mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperatures of combustion
5. Accurate temperature control
6. Uniform quality of product
7. Minimum damage to product
8. Cleanliness of plant
9. Low fire risk
10. Minimum scale
11. Freedom from tar
12. Continuous furnaces may be used
13. Long life of furnaces

DISADVANTAGES

1. Cost of installation
2. Installation more complicated than for oil, natural gas or city gas
3. Handling of fuel
4. Disposal of ash

5. Operating labor
6. Restricted fuel supply
7. Menace to life and health due to odorless gas
8. High cost of gas per b. t. u.
9. Danger of back firing due to rapid flame propagation

Cold, clean producer gas—efficient use limited to about 2000 degrees Fahr. unless recuperative or regenerative furnaces are used

ADVANTAGES

1. Can be burned efficiently
2. Low temperature of combustion
3. Accurate temperature control
4. Uniform quality of product
5. Minimum damage to product
6. Continuous furnaces may be used
7. Long life of furnaces
8. Reliability of fuel supply
9. Stability of fuel cost
10. Minimum scale
11. Comparatively low fuel cost

DISADVANTAGES

1. Cost of installation
2. Handling of coal
3. Disposal of ashes
4. Large pipe mains
5. Operating labor
6. Installation more complicated than oil, natural gas, or city gas

Coal—Can be used efficiently only for long heat service

ADVANTAGES

1. High efficiency
2. Low fuel cost
3. Life of container boxes longer than with oil
4. Total operating cost low
5. Reliability of fuel supply
6. Stability of fuel price

DISADVANTAGES

1. High initial cost
2. Repair of firebox due to high combustion temperature
3. Floor space occupied
4. Coal and ash handling
5. Difficulty in keeping competent firemen

Electricity Limited to temperatures below 2000 degrees Fahr.

ADVANTAGES

1. Absolute temperature control
2. No high combustion temperatures
3. Long life of furnaces
4. Simplicity of installation
5. Elimination of piping mains, pumps, and blowers
6. Simplicity of operation
7. Automatic continuous equipment applicable to any service
8. High efficiency

9. Minimum labor cost
10. Small floor space occupied
11. Flexibility
12. Cleanly plant conditions with consequent high morale
13. Quality of product
14. No damage to product
15. Minimum scale

DISADVANTAGES

1. High first cost

We have been able to only superficially scan one small phase of the all important subject of fuel economy. We are well aware of the lack of technical refinement in the arguments presented and that our conclusions are based upon more or less empirical methods of deduction, but as the results are substantiated by tests, they should prove of some value. We are content if this paper serves to stimulate an active interest in the minds of a few upon the subject of furnace operation and economy, because with our existing methods it is safe to claim that at least one-half the *fuel used* in industrial furnaces is now needlessly wasted.

A NEW METHOD OF CASE HARDENING STEEL

By William J. Merten*

(A Paper Presented Before Pittsburgh Chapter)

Iron and low-carbon steels absorb carbon from socalled carburizers very readily when in contact with these carbonaceous materials at temperatures above the upper critical point. The quantity of carbon absorbed depends upon several factors. One of these is the temperature or degree of heat above the critical point of the steel. In other words, the higher the temperature, the faster and deeper the penetration of the carbon.

The character of the carburizer is also an important factor in the successful conductance of case hardening including the depth of the case. Elementary carbon as such is only of secondary importance. Oxygen and nitrogen compounds which are added or are naturally present in the socalled energizers are necessary to generate nascent gaseous carburizing mixtures of carbon monoxide and cyanogen gas (CO and CN).

The percentage of carbon present in the steel used for case hardening has also a marked influence upon the affinity of the material for more carbon up to saturation; more specifically, a low carbon steel absorbs faster than high carbon steel.

The presence of chromium tungsten, or manganese accelerates the absorption of carbon since they form double carbides with the iron. Nickel and silicon, however, retard the absorption. The fact that they form solid solutions with iron may be the cause for this retardation.

From statements made in the second paragraph it is readily conceivable that, if a properly heated piece of steel be brought into contact with pure nascent gas continuously generated in a separate unit or chamber and preferably under pressure, the conditions for case penetration would approach the ideal. A process of this type is the one presented in this paper, preceded by a survey of the processes now in vogue with their disadvantages and deficiencies.

*Metallurgical engineer, Westinghouse Electric & Mfg. Co., Pittsburgh.

The most general and commonly used method of case hardening is conducted by packing steel parts in a metal box filled with carburizing materials and firing the tightly closed box and contents at a sufficiently high temperature for an adequate length of time to give the desired depth of case. This process is quite simple and assures fair success if properly conducted in accordance with a prescribed procedure, experimentally determined to give certain definite results under definite and specific conditions.

The disadvantages of the above process are as follows: (1) uncertainty of proper reaction within closed box; (2) difficulty in duplication of results as predetermined, because of non-uniformity of carburizers; (3) long time exposure of the steel to a heat not well controllable, producing a questionable structural condition; (4) high cost of operation because of inefficiency of the heating method; (5) cost of boxes due to rapid deterioration of same by oxidation.

The second method to be mentioned is case hardening by immersing the steel article in a cyanide bath heated to about 1580 degrees F. This process is convenient and effective on small articles only and where the depth of the required case is not more than .005 in. to .015 in., or where mere surface hardening is wanted. This is a fast caseforming method and from 10 to 15 minutes gives the desired depth. The outstanding disadvantage of this process is that no uniform case can be produced. The parts deep in the melted bath do not get the same depth of penetration as the parts near the surface. The evolution of the cyanide gases at or near the surface favors the penetration and it is hardly feasible to have pots with a large enough surface area to take care of the case hardening of a plant.

The third method consists of dipping a cherry red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, ferro and ferri cyanides, or sprinkling the powdered salt of these cyanides on the red hot steel surface and putting the steel back into the fire again. The case hardening produced in this way is very superficial. In the fourth method the carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design.

The process to be discussed next, although still in the experimental stage, owing to radical changes in the principle employed, appears to present opportunities for efficiency, preservation of the product, simplicity of operation, uniformity of results, speed of operation, reasonable cost, and wide range of utility. This process may be called a regenerated cyanogen gas case hardening.

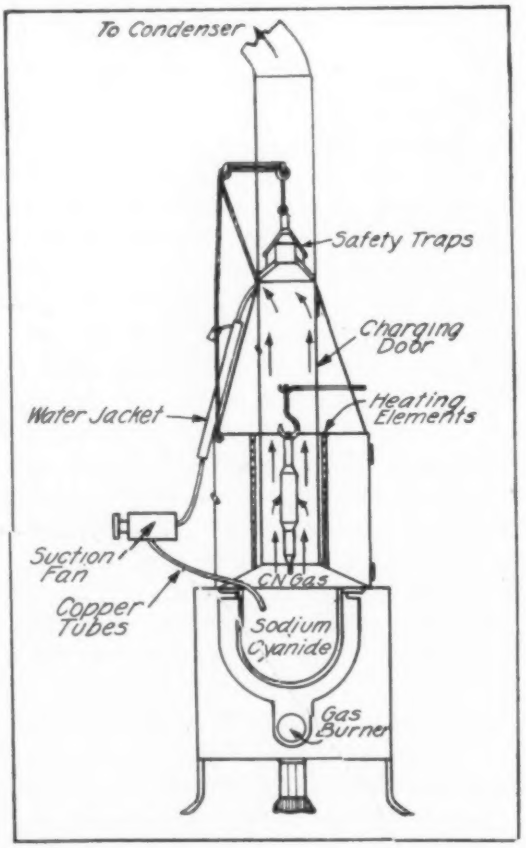
It has long been recognized that the most efficient carburizing gas is cyanogen (CN). The case is of a greater uniformity, is more rapidly produced and penetrates deeper than one produced by carbon monoxide (CO), but the highly poisonous character of the substance has been a serious objection to its use. The tendency is to lead the gas wastefully to the stack and out of harm's way, instead of controlling it to get maximum efficiency.

To case harden steel and iron alloy articles in a stream of cyanogen gas evolved from a container filled with an alkali cyanide salt, heated by electrical energy or other means to accomplish vaporization or boiling of the salt, is the principle upon which this process is based.

The articles or materials to be processed are independently heated

out of contact with the fused cyanide salt. The advantage of this will readily be appreciated on recalling the statements made regarding the fact that case hardening is produced by contact with gaseous and not with solid carbon and more especially with cyanogen gas. The depth of penetration is then only a function of the uniformity of the temperature of the article treated and the duration of treatment. Nascent cyanogen has a speed of penetration of four or five times that of carbon monoxide.

The furnace shown in the accompanying illustration embodies the regenerative principle since the excess gases not absorbed by the steel are forced under pressure into the fused cyanide (CN) bath, are reheated, causing a vigorous stirring of the bath, and a lively evolution of cyanogen gas, leaving with more energy and larger quantities, therefore more vigorously attacking the steel surface, causing accelerated and deeper penetration.



In this furnace the piece to be case-hardened is suspended vertically between the heating elements where it is heated to the proper temperature. Cyanide salts in the container below are heated by a gas burner which causes them to evolve cyanogen gas. As this gas passes to the top of the furnace a certain amount of it is absorbed by the steel while the balance, by means of the suction fan is returned to the bath. This produces a stirring of the bath and more rapid evolution of the cyanogen gas to surround the steel and cause a deeper penetration. Upon charging or removing the steel, the safety trap opens and the fan stops to prevent the poisonous gas from escaping through the charging door.

This regenerative type of furnace is a means to use the rather expensive salt economically, as the nitrogen gas on returning will combine with the sodium and a carbon supply in some cheap form such as charcoal can be added to the liquid as required, thereby retaining the original supply of cyanide salt intact.

To prevent the poisonous gases from escaping into the room, the suction fan indicated is shut down before the charging door is opened and a bell ventilating device for inducing draft is arranged so as to open the bell when the fan stops and prior to opening the door.

Parts of the pump or suction fan should be of nonferrous metals such as copper, basic alloys or hard copper. Water cooling jackets or

other protective methods are to be employed for the return flues for hot gases and the nozzle end of the flue must be of hard copper, monel metal or other non-ferrous alloy with a high melting point.

Sodium cyanide melts at 1112 degrees Fahr. and boils at 1472 degrees Fahr. The temperature of the pot must therefore be not less than 1472 degrees Fahr. and to effectively absorb this gas the steel is at a temperature above the critical point or about 1650 degrees Fahr.

The furnace illustrated in the illustration is a design for the processing of shafts, etc., but a slight modification of the upper or steel heating chamber will adapt it to a variety of work. Grates of nichrome metal with knife edge supports are used.

The advantages of this process are the following: (1) temperature control is more perfect since the pyrometer is inserted directly in the heating chamber; (2) a finer, more uniform, and deeper case can be secured than by any other processes and less time is required; (3) the use and storage of carburizers and carburizing boxes is eliminated.

It should be noted that while some of the less important features of this process are still speculative in character, because of the experimental stage of the development, the method is based upon well known principles and the conclusions have been drawn from a careful study of general case hardening practice.

SERIES OF ARTICLES ON CARBONIZING PROCESS

Beginning with the March issue of Transactions will be published the first of a series of 10 illustrated articles discussing the case carbonizing process written by Theodore N. Selleck, Chicago. The subject of the first article will be "First Principles of the Carbonizing Process—A Consideration of the Fundamental Facts and Factors of the Process." Titles of the other nine articles will be as follows: "The Relation of Temperature to the Quality of the Case and Core;" "The Relation of Time and Temperature to Depth of Case;" "Comparative Tests of Steel Samples, Carburized and Heat Treated at Different Temperatures;" "Comparative Tests of Steels of Various Types Subjected to Uniform Treatments;" "A Study of Quenching Temperatures and Media;" "Tests for Wearing Qualities of Case Hardened Parts;" "The Application of Gaseous and Liquid Fuels;" "A Study of Methods Employed for Selective Case Hardening;" and "Special Methods Employed in Unusual Applications of the Process."

News of the Chapters

The many chapters of the American Society for Steel Treating have been holding meetings regularly during the winter months, yet it is impossible to give a complete write up of each meeting. Nevertheless, the speakers and the salient points of the meetings are given.

Practically all of the chapters have had membership campaigns on and in spite of the general conditions these have been very successful. Many very interesting letters and announcements relative to increase

in memberships have been received by the national office two of which are reprinted, in this issue.

A Letter

Following is a letter which was sent out by the chairman of the membership committee, Mr. Knerr, of the Philadelphia chapter, to all members of the local chapter:

Dear Sir:

"As a member of the Philadelphia Chapter of the American Society for Steel Treating, you are on the Membership Team. (This is explained in Bulletin No. 1, enclosed.) Will you do *your* part to build up this Chapter,—YOUR Chapter, of the A. S. S. T.?

"The Society as a whole is growing rapidly. There is a Campaign for 25,000 members in the National body, and that goal is likely to be reached soon. The Philadelphia Chapter must meet the pace. More than that, we must get to the head of the procession, where we belong.

"Philadelphia is the greatest industrial center in America. A large proportion of all its numerous and varied industries depend in some measure upon the proper heat treatment of steel. In many of them, heat treated steel, in some finished form, is the principal product. Of the others, there is hardly a modern plant that does not have at least its Tool Shop, where tools, jigs or parts are made, repaired and *heat-treated*. Moreover, we are leaders in the production of high grade steel, pyrometers, metal testing machines, heat treating equipment and materials. The arts and sciences connected with the treatment of steel are taught in our trade schools and engineering colleges.

"Therefore, you see that there are literally thousands of men in and around this city who are concerned with the treatment of steel. For these men the A. S. S. T., and in particular, the Philadelphia Chapter, exists. It needs them. They need it.

"Our Chapter should number 1000 members by January 1, 1921. This is some contract. Can we make it? Whether we can, depends upon *you* and every other live member.

"When you joined the Society you agreed, in your application, to promote the objects of the Society insofar as it should be in your power. Perhaps you have not yet had an opportunity or the inclination to present a paper or to render any other special service; or perhaps you have already served in many ways. In either case, this is a chance to do something worth while, something of direct benefit to the Society, to yourself and to your friends. A bigger and better Chapter means greater value to every member.

"You, no doubt, know personally a number of men whose membership in the Society would be a benefit to themselves and to us. Other such men are near you in your office or plant, or in your daily path, if you will but take the trouble to look them up.

"Make it a point to see each of these men without delay. Tell them about the "Steel Treaters," what the Society is and does, and why *you* are in it. Show them a copy of the TRANSACTIONS. Bring them with you to the next meeting.

"If they are qualified to join, sign them up, indorse the application, and send it in.

"Here are the qualifications for membership:

"'All persons of good character who are in any way interested in the work of the Society are eligible for admission to the same." (The Constitution A. S. S. T., Article V, Section). The initiation fee is temporarily suspended. A deposit of $2.00 places a man on the rolls.

"Yes, we know you are busy, but remember,—"Every man owes some of his time to the upbuilding of the profession to which he belongs."—T. R.

"Will you do *your* part *now?*

H. C. KNERR, Chairman
Membership Committee."

"P. S. Some people out West *think* we are asleep. Can they prove it by YOU?"

Another Letter

"Bill" Abel the active chairman of the membership committee of the Cleveland chapter drafted the following letter which was sent out to 500 firms in the vicinity of Cleveland, and which produced good results:

"Your product being one in which the proper heat treatment of steel is very essential suggests to us the thought that you or some of your representatives would be interested in the American Society for Steel Treating.

"The many advantages to be derived from becoming associated with metallurgists, chemists, managers, superintendents and steel treaters are evident. The opportunity of meeting these men and the exchange of ideas should be very valuable to you.

"A membership in this Society entitles one to attend the meetings, which are held once a month or oftener, at which time an interesting paper is usually read by some notable in his particular line.

"The next meeting will be held at the Hotel Statler in the rooms of the Cleveland Engineering Society, dinner to be served at 6:30 and the meeting at 8:00 p. m. The speaker for the meeting of December 27 will be Mr. W. E. Jominy, Metallurgist for The Packard Motor Car Co. His subject will be: "The Selection and Treatment of Materials for Automobiles".

"In addition to the privilege of attending these meetings, members receive the regular monthly publication which has become recognized as the leading journal devoted to heat treating and allied lines.

"If you desire further information regarding the aims of the Society, kindly drop us a line and we will have a member call on you to explain in full its objects and advantages.

Yours very truly,

W. ABEL."

"P. S. We wish to extend to you a very cordial invitation to attend the next meeting of the Society, which will be held as stated above. Come to the dinner if you can."

ANNUAL VISITS BY THE NATIONAL PRESIDENT

Lieut. Col. White, national president of the American Society for Steel Treating, will visit a number of the Eastern chapters during the mid-semester recess of the University of Michigan.

President White's itinerary calls for the following schedule:

Monday, February 7............................Boston
Tuesday, February 8 ....New Haven
Wednesday, February 9 ....Bridgeport
Thursday, February 10 ....Hartford
Friday, February 11 ....Springfield
Monday, February 14 ....Providence
Tuesday, February 15 ....New York
Wednesday, February 16......................Philadelphia
Thursday, February 17 ....Baltimore
Friday, February 18..........................Washington

MILWAUKEE CHAPTER

H. J. Stagg, assistant general manager of the Halcomb Steel Company delivered an address before the Milwaukee chapter on Dec. 15, at the Hotel Medford. The meeting was preceded by a dinner which was quite largely attended and the meeting proved very interesting. The discussion was lively.

ST. LOUIS CHAPTER

Prof. J. H. Keller, professor of mechanical engineering at the Lewis Institute, Chicago, addressed the members at the December meeting at the Planters' Hotel, on Monday evening, Dec. 13. The attendance was quite large and all thoroughly enjoyed Prof. Keller's address on "Steel, Its Selection and Treatment." The discussion was voluminous and the meeting enjoyable.

BALTIMORE CHAPTER

The November meeting was addressed by Marshal Medwedeff, formerly of the Sampson Tractor Co., Danville, Wis. Mr. Medwedeff selected as his subject, "High Speed Steel," which proved to be very interesting and instructive. The discussion following the address brought

out many important points with reference to the treatment of high speed steel.

The December meeting was addressed by G. S. Hamlin, Jr., of the Atlas Crucible Steel Co., Dunkirk, N. Y., who spoke on "The Manufacture and Uses of Alloy Steels," illustrating his talk with moving pictures. The meeting was held in the assembly room of the Consolidated Gas Electric Light & Power Co.'s building and a large audience was well attended. Everyone thoroughly enjoyed the talk by Mr. Hamlin.

BOSTON CHAPTER

S. C. Spalding, metallurgist of the Halcomb Steel Co., Syracuse, N. Y., delivered a very interesting paper before the chapter in the Engineers' Club, on Dec. 20. The discussion was of a very practical nature and full of valuable experiences. At the close of the meeting an excellent buffet lunch was served to 80 members in attendance.

On Jan. 7, Maj. A. E. Bellis of the U. S. Arsenal, Springfield, presented an interesting and enjoyable paper on "Some of the Essentials in Treating High Speed Steel." The discussion was very general and keen, and the meeting proved very enjoyable and profitable. Over 100 were in attendance.

PROVIDENCE CHAPTER

The regular monthly meeting for November was held on Wednesday evening, Nov. 24 at the Providence Engineering Society rooms. The speaker was E. F. Collins, consulting engineer of the General Electric Co., who read a paper on "Relative Thermal Economy of Electric and Fuel Fired Furnaces." The paper was illustrated with lantern slides. Mr. Collins is a leader in the electrical furnace field, and he presented a paper which amply repaid all those members who attended. The discussion was quite interesting and many important questions were propounded to the speaker and successfully answered.

The December meeting was held on the 29th at the Providence Engineering Society rooms when A. H. D'Arcambal, consulting metallurgist of Pratt & Whitney Co., gave a very interesting paper on "Hardening of High Speed Steel." The discussion following the presentation of Mr. D'Arcambal's paper was such as to show that the selection of the subject was very appropriate and that the members decidedly were interested in the subject.

HARTFORD CHAPTER

The December meeting of the chapter was attended by 100 members of the Society. The meeting was held in the Chamber of Commerce auditorium on the 9th. The speaker of the evening was Charles Green, chief chemist of the Henry Souther Engineering Co., who presented a paper on "Fundamental Chemistry." George Jayne, of the Peter A. Frasse Co., spoke on the subject of "Manganese."

There was a good discussion on the papers and an interesting phase of the meeting was the opening of the question box where there had been deposited a number of questions relative to the problems confronting the members of the Society. These questions were answered to the satisfaction of the members present. At the close of the meeting refreshments were served.

PHILADELPHIA CHAPTER

The November meeting was held in the auditorium of the Engineers' Club, and was attended by about 100 members and guests. A paper was

presented by Dr. W. M. Mitchell, metallurgist, who selected as his subject, "Troubles|" Dr. Mitchell illustrated his talk. At the close of the presentation of the paper, an excellent discussion was entered into with a great deal of freedom by the members and guests.

The results of the extensive campaign carried on by the Philadelphia chapter have begun to make themselves shown in the increased attendance and the interest of the members.

The January meeting was held at the Engineers' Club, on Saturday evening, January 8, when G. W. Tall, of the Leeds & Northrup Co., presented an illustrated paper on the "Hump Method of Heat Treatment." Mr. Tall had a furnace in operation during the talk and gave practical demonstrations of the work.

CHICAGO CHAPTER

As results of opening up of educational courses at the Armour Institute and at the Lewis Institute, under the auspices of the local chapter, three classes have been organized and are full to capacity. Two of the classes are located at the Armour Institute, and one at the Lewis Institute.

A great amount of credit is due to T. E. Barker the chairman of the educational committee and to the various members of his committee and also to the Chicago chapter who have devoted largely of their time and efforts in the preparation of the text for the courses.

The December meeting was held at the Lumbermen's Association, fourth floor at 11 S. LaSalle St. A dinner was served at 6:30 to 125. The speaker of the evening was H. J. Stagg, chairman of the Syracuse chapter and a member of the Board of Directors of the National Society. Mr. Stagg presented a very interesting paper, illustrated, which was received heartily by the large number in attendance. The discussion following was quite open and free. Following is an extract of a report from the secretary of the Chicago chapter with reference to the above meeting:

"We all knew that Stagg had something good, but even at that he surprised us. You know how hard it is for a speaker who is giving even only a little theory with his paper to hold his audience. Well, last night the men "ate" all that Howard J. was feeding, and when, for the nth time he remarked, 'heat slowly, thoroughly, and evenly, etc.,' one could be sure that the above at least had "gone home" with everyone present."

PITTSBURGH CHAPTER

C. M. Brown, vice president of the Colonial Steel Co., presented a paper on "Standard Specifications of Tool Steels" before the Pittsburgh chapter at its December meeting at the Chatham Hotel. This subject, since it is becoming more and more important daily, is one which the manufacturer and consumer have to wrestle with, brought out a good attendance as the members were very anxious of getting the facts from one who is thoroughly familiar with tool steels. The National Secretary was supposed to have been present at this meeting but was prevented from doing so by illness.

SYRACUSE CHAPTER

The second regular meeting of the Syracuse chapter was held on Nov. 23 in the rooms of the Technology Club in the Vinney Building. The speaker of the evening was Frank Lounsberry, metallurgist of the Atlas Crucible Steel Co.

The "baby" chapter came through with an attendance that far surpassed even the most optimistic expectations. It had arranged for the use of the auditorium of the Technology Club, which room will seat about 150. Before 8 o'clock the room was filled and then overflowed into a connecting room. There were 250 in attendance by the time all arrived. The speaker was very enthusiastic in his remarks about the spirit of the meeting. The applications for members in the chapter number 120. As soon as business conditions revive the Syracuse chapter will have no difficulty in hitting the "bull's-eye" at 250.

The third meeting of the chapter was held in the same rooms on Tuesday, Dec. 21, with J. V. Emmons, metallurgist of the Cleveland Twist Drill Co., as the speaker. Mr. Emmons presented a paper on "Tool Hardening Problems," illustrated. When the invitations were sent out, the members were requested to bring their problems with them. This, they did, and consequently a very lively and enjoyable meeting was held. A dinner was served in the dining room adjoining the auditorium.

BUFFALO CHAPTER

John Miller, well known metallurgist of the Pierce Arrow Motor Car Co., presented a paper on "Fatigue Breakdown of Metal." Inasmuch as probably no other man in or about Buffalo has as many varied steels to work on as Mr. Miller, his paper proved to be very enjoyable and instructive. The meeting was held on Monday, Dec. 6 at the University Club.

The January meeting was held on the 4th of the month at the University Club when a paper was presented by Mr. H. J. Stagg. The attendance was very satisfactory and the meeting was preceded by a dinner. An extensive discussion followed Mr. Stagg's paper and many of those present gathered a new idea as to the important function served by the local chapter in the community.

BRIDGEPORT CHAPTER

The December meeting of the Bridgeport chapter was held in the parlor of the Stratfield Hotel, on Dec. 16. C. W. Copeland, metallurgist of Hare's Motors, Inc., presented an interesting illustrated lecture on "Metallography and Microstructure of Steel." This was the first of a series of lectures on this branch of steel treating, and a large number were in attendance as they desired to secure a thorough understanding of this important subject.

SPRINGFIELD CHAPTER

The November meeting was held on the 29th of the month in the Chamber of Commerce hall, and was addressed by W. J. Kaup, consulting engineer, New York, who selected as his subject, "Steel and the Man." Mr. Kaup has an international reputation, and the large attendance of the members felt well repaid for having been in attendance because Mr. Kaup's paper was interesting and instructive, and the discussion following it very enlightening.

W. R. Shimer, sales metallurgist of the Bethlehem Steel Co., presented an illustrated talk on "Manufacture of Steel," before the Springfield chapter on Friday evening, Dec. 17. The session was held in the Technical High School Hall in order that they might have the facilities for moving pictures. Mr. Shimer commenced with the ore, and continued through the blast furnace to the converter into the open hearth

furnace and also the crucible, ending with a detailed talk on manufacturing tool steels. Mr. Shimer has a very pleasing personality and it was a pleasure to all of the large number in attendance to have had the opportunity of listening to him and enjoying the paper.

The January meeting of the Springfield chapter was held in the auditorium of the Springfield Gas Light Co.'s building. James Cran, demonstrator for the Ludlum Steel Co., Watervliet, N. Y., gave practical demonstrations of the "Forging and Heat Treatment of Carbon and High Speed Steels." This was followed by an exhibition of artistic forging. The meeting was without doubt one of the most interesting which the Springfield chapter has had. Practically all of the members were in attendance.

CINCINNATI CHAPTER

The December meeting of the Cincinnati chapter was held on Friday evening, Dec. 10, in Hall D, Odd Fellows' Temple. The following program was run off on schedule time.

7:30 p. m.—Important business transacted.
8:00 p. m.—"EFFECT OF THE ELEMENT CARBON ON STEEL" by W. L. Fleming, metallurgist of the Andrews Steel Co.
8:15 p. m.—Discussion on the above subject.
8:30 p. m.—"FURNACES AND FUEL"—with special emphasis on conversion from gas to oil—By Dr. J. C. Hartzell.
9:30 p. m.—Comments on the last issue of the Transactions, the publication of the American Society for Steel Treating, and an open discussion on same.

The meeting was very well attended and proved very profitable.

DETROIT CHAPTER

The meeting on Dec. 20 was held in the Board of Commerce rooms at which a round table meeting took place, on the interesting subject of "Carbonizing." Following are the speakers, and each one prepared a ten minute paper on the subject:

A. T. Haggerty—Central Gear Co.
John Secholtz—General Motors Co.
Herbert M. Bray—Lincoln Motors Co.
H. G. Kiefer—Studebaker Corp.
L. A. Danse—Cadillac Motor Car Co.
J. M. Watson—Hupmobile Motor Co.

A discussion followed the presentation of each paper. This round table idea has proven itself to be of real value in having presented the ideas of the members on some subject. The way those in attendance entered into the discussion and asked questions proved conclusively that more meetings of this particular nature would be especially desirable.

The November meeting proved to be one of exceptional interest. It was addressed by J. A. Brown, vice president of the W. S. Rockwell Co., New York. Mr. Brown selected as his subject, "Factors Governing the Production of Heated Products." Mr. Brown thoroughly understands the subject on which he talked, and consequently was able to answer the many questions propounded to him. Over 100 were in attendance.

TRI-CITY CHAPTER

Harold Brown, the active, wide-awake secretary of Tri-City chapter, ends his announcement of the meeting for Dec. 16 with this sentence:

"We expect to see your smiling face Thursday evening." That together with the fact that all the members with machines are hauling to and from the meetings those who do not have them, assisted in bringing out a large attendance. The speaker of the evening was Dr. French, chief chemist of the Dearborn Chemical Co., who presented a real message regarding "Quenching Mediums," and the greatest enemy of the metallurgical world, "Rust." The meeting in point of interest was one of the best which the local chapter has held.

SCHENECTADY CHAPTER

The opening meeting of the Schenectady chapter was held on Dec. 7 in the metallurgical laboratory of the American Locomotive Works. Prof. McKibben, instructor in civil engineering at Union College gave a talk on "Tests on Full Size Steel Plate Girders." E. J. Edwards, engineer of tests at the American Locomotive Works also gave a short talk. A short business session was held after which light refreshments were served. It was the privilege of all present to have access to all parts of the new metallurgical laboratory of the American Locomotive Works. First hand information was gained as to how heat treating problems are solved. Men were present to explain details of operation of apparatus or machinery in which the various members were interested.

The January meeting was held at the same place on the 7th of the month, when G. R. Brophy, research metallurgist of the General Electric Co., presented a talk on "True Action of Cyanide in Case Hardening," and spoke also on "Nitrogen Content in Carbonized Cases." Considerable time was devoted to discussion, and interesting questions were brought out.

CLEVELAND CHAPTER

The December meeting of the Cleveland chapter was held in the rooms of the Cleveland Engineering Society, on the 27th. Dinner was served at 6.30. The speaker of the evening was W. E. Jominy, metallurgist of Packard Motor Car Co., who selected as his subject, "The Selection and Treatment of Materials for Automobiles." The paper was of such a nature that it was unusually interesting to everybody present. All of the officers and the Board of Directors of the National Society were present at this meeting, inasmuch as they had held a conference in Cleveland on that day.

INDIANAPOLIS CHAPTER

The December meeting of the Indianapolis chapter was addressed by Mr. J. V. Emmons, metallurgist of Cleveland Twist Drill Co. Mr. Emmons, because of his broad experience in this particular branch of heat treating, handled his subject, "Tool Hardening Problems," in a very thorough and capable manner. E. Haynes, of Kokomo, who is one of the original members of the Society, and who is at present serving on the United States grand jury in Indianapolis, was presiding officer at the meeting. The discussion was of a very interesting nature, and the meeting proved to be a decided pleasure to all those in attendance.

The January meeting was held in the Chamber of Commerce rooms on th 10th of the month when H. E. Hayward, metallurgist of the Link Belt Co., presented an illustrated lecture on "Malleable Iron." Mr. Hayward handled his subject in a very intelligent manner and brought out many points of decided interest to those present.

TOLEDO CHAPTER

The December meeting was held in the rooms of the Chamber of Commerce on the 9th of the month, when a paper was presented by S. C. Spalding of the Halcomb Steel Co., Syracuse, N. Y. The meeting was preceded by a supper, and was attended by about 50 members and guests.

NEW YORK CHAPTER

On Nov. 17, W. R. Moore, sales engineer of the Norton Co., Worcester, Mass., presented a very interesting paper on "Grinding." Inasmuch as practically 90 per cent of the difficulties with heat treated products encountered is due to faulty grinding, this subject proved to be very interesting and gave the heat treaters an opportunity to lay some of their difficulties at the proper source. A very interesting discussion followed the presentation of Mr. Moore's paper.

The December meeting was held at the Machinery Club on the 15th, when H .P. MacDonald, of Snead & Co., Jersey City, presented a paper on "Electrical Heat Treating of Steel." Over 100 were present at the meeting and all contributed to making it a very lively one.

NORTHWEST CHAPTER

The December meeting of the North West chapter was held in the Manufacturers' Club rooms in the Builders' Exchange Building, at Minneapolis. Over 100 members and guests gathered to greet H. J. Stagg, a member of the National Board of Directors. Mr. Stagg presented a very interesting paper that met with the hearty approval of the large number present.

On Jan. 17, Mr. Richardson, of Midvale Steel & Ordnance Co., presented a six reel moving picture on the "Manufacture of Iron and High Speed Steel." Mr. Richardson's talk accompanying the slides was very interesting and at the close of the meeting a lively discussion was participated in by many present, while all joined in enjoying the buffet lunch which was served by the chapter.

A. F. McFarland, of the Vanadium Steel Alloy Co., presented a paper at the monthly dinner of the chapter on Tuesday, Nov. 30. Mr. McFarland selected as his subject, "Some Notes on Heat Treatment and Structure Characteristics of High Speed Steel." Mr. McFarland's paper was illustrated by lantern slides. Over 100 took the opportunity to profit by his highly interesting and educational paper.

THE ADVANCEMENT OF HEAT TREATING STEEL

(Portions of a Communication to President A. E. White)

The members of the American Society for Steel Treating may rest assured of the appreciation afforded a pioneer of heat treating in observing the remarkable advancement in the science of heat treatment of steel since the writer 31 years ago suggested and made the first tentative efforts, of annealing and systematically heat treating steel car axles. Prominent metallurgists ridiculed his use of the microscope. The revelations of the refinement of processes of how to treat steel scientifically shown at the recent convention and exhibition by the Society at Philadelphia, indicated

AMERICAN SOCIETY FOR STEEL TREATING.

Hartford Chapter

PROGRAMME
1920 - 1921

	PRACTICAL DEVELOPMENT OF STEEL FROM ORE TO TREATER	DISCUSSION OF ELEMENTS AND TREATMENT	BALANCE OF TIME
Nov. 11,	Ore - Coke	Phosphorous & Sulphur	
Dec. 9,	Fundamental Chemistry	Manganese & Spiegle	Are's and "Aints"
Jan. 13.	Blast Furnace	Carbon & Silicon	Terminology
Feb. 10,	Wrought Iron	Nickel	
Mar. 10.	Bessemer	Chromium	Special Papers
Apr. 14.	Open Hearth	Vanadium	To be announced
May. 12,	Crucible & Electric	Tungsten	
June 9.	Fabrication	Molybdenum, Titanium, Cobalt	

"DON'T BE A SPONGE, BUT IF YOU MUST, ONCE IN A WHILE GIVE YOURSELF A SQUEEZE."

D.H. STACKS Chairman — M.E. GERE Vice Chairman — C.T. HEWITT Sec. & Tres.

COMMITTEES

EXECUTIVE		PROGRAM	FINANCE	ENTERTAINMENT		MEMBERSHIP
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decidedly that the world and the American engineer move, and move rapidly, when occasion requires.

It was a pleasure to study that exhibit with its refinements and then hark back to the strenuous times of 35 and 40 years ago when it was difficult to convince the steelmaker and forger that good steel could be spoiled by improper heat treatment and bad steel could be improved by judicious heat treatment, and that the boilermaker's mistreatment of steel plate, by persistent treating and flanging steel like wrought iron plate, caused the steelmaker to produce a metal so honeycombed that it soon failed in service. The reason for the latter was that honeycombed steel plate more constantly displayed the flanging qualities required by the boiler maker. That was the reason Barba of France, when first using steel for the French navy, put carpenters in the smith shop to heat and flange the steel because they, knowing nothing about working metal, were willing to follow Barba's direction of steel treatment.

There is one vital feature, however, to be observed when treating steel of any kind and composition, and one which holds as good today as it held good 40 years ago, and that is the observance of a judicious and careful rate of heating and cooling of the steel. An ideally uniform and homogeneous steel coming from the melting pot or the furnace is not known and if it were known, rapid heating or cooling would change that uniformity. Hence, a cardinal principle of steel treatment is slow heating and cooling, except for hardening, because of the different melting points of the elements composing the steel. Since the various elements in the steel travel at a given degree at a given heat, trying to establish an equilibrium according to their chemical affinity, if insufficient time is given for the various elements to dissolve and to diffuse gradually through the mass, the result will be as heterogeneous a metal as it was before heating, possibly more so. It is remarkable how even inferior steel can be improved and made serviceable by slow heating, which allows sufficient time for the diffusion of elements.

When steelmaking and using was in its infancy for structural purposes, an endless variety of difficulties arose due to lack of experience. Segregation was particularly troublesome and it was remarkable that slow heating and consequent chance for diffusion of elements reacted to make segregated steel serviceable where the forces of destruction were not too varied and complex. To the young engineer, who is eager for quantity production, this property of steel demanding time and patience for the diffusion and equalization of elements to attain and equilibrium of forces, is often trying if not harassing, but it is a natural law, the nonobservance of which confirms the old saying that haste makes waste.

Paul Kreuzpointner,
1400 Third Avenue,
Altoona, Pa.

Commercial Items of Interest

John L. Cummings, until recently connected with the S. Obermayer Co., is now secretary of the Mac Co., Inc., 293 Thirty-fourth avenue, Milwaukee,

a new company which he organized. The company will manufacture refractories and foundry materials. Mr. Cummings was in charge of the S. Obermayer Co. exhibit at the recent Philadelphia convention of the society.

John C. Pangborn, vice president of the Pangborn Corp., Hagerstown, Md., manufacturer of sand-blasting and allied equipment sailed from New York Nov. 27 on THE OLYMPIC for Southampton, Eng. He will spend several months in Europe on business.

W. S. Rockwell Co., 50 Church street, New York, has issued an 8-page bulletin, on heat treatment furnaces of the car and car and ball type. This pamphlet, which is illustrated, points out the applicability of car type and car and ball type furnaces to the heat treatment of material that can not be handled advantageously in other types of furnaces. The discussion includes factors governing selection of the type best suited to individual manufacturing requirements; influence of unequal cooling on the quality of the finished product; and typical heat treatment installations involving the use of car and car and ball type furnaces.

H. R. Harris, manager of the metals division of the Quigley Furnace Specialties Co., New York, has purchased from the Quigley company this department including all rights related to the products and will handle this business on a more extensive scale under the name of the General Alloys Co. Headquarters will be maintained at 122 S. Michigan avenue, Chicago, and 26 Cortland street, New York, while branch offices will be established in principal cities. A local sales office will be located in the Chemical building, 117 North Dearborn street, Chicago. Mr. Harris founded the metals division of the Quigley company and has been its manager from the start. Mr. Harris has had wide experience with heat resisting materials and is considered an authority on the subject. He is the author of numerous articles on heat treating containers, high temperature resisting alloys, etc., and has designed heat treating equipment for many of the largest plants in the country.

Mr. Harris was formerly associated with the Diamond Power Specialty Co., and the Calorizing Corp. of America in executive capacities, and prior to his connection with the Quigley company, was general manager of the Swedish Crucible Steel Co. The General Alloys Co. will continue with the offices formerly occupied by the metals division of the Quigley Furnace Specialties Co., New York, Detroit and other cities and is retaining a large part of the former organization including P. F. McGovern, A. L. Grinnell and H. P. Rounds and others. Mr. Harris plans to increase this organization soon.

J. P. Greenwood, mechanical engineer, is now associated with the Smith Gas Engineering Co., Dayton, O., as southwestern representative. Through his former position as Texas representative of the N. A. S. E. and years of contact with southwestern plant. Mr. Greenwood has formed a wide circle of friends and little introduction is needed to power users in southwestern states. Mr. Greenwood will introduce the gas producer in one of its most promising fields. Southwestern fuel, particularly lignite, is considered satisfactory for use in gas producers, and Mr. Greenwood will endeavor to show economies made possible through the use of lignite in generating gas power, either as engine or industrial fuel. His headquarters will be 219 Cotton Exchange building, Dallas, Tex.

Concluded on Page 43, Advertising Section

The Melting Pot, a monthly house organ of the Chicago Flexible Shaft Co., Chicago, contains in each issue brief articles on heat treating practices of a technical nature. Considerable worth-while information for the steel treater is to be found in this little publication. Features of the September issue were: "Worth While Hints on Annealing"; and "Heat Treatment of High Speed Steel"; and of the November-December issue: "A Sharp Talk on Carburizing"; "Development and Use of Pyrometers"; "Carborundum Refractories"; and "Insulation of Industrial Furnaces".

Ethan Viall, editor-in-chief of the *American Machinist,* who has been with that publication for ten years, has resigned to become a partner in the firm of T. W. Minton & Co. Barbourville, Ky., one of the largest producers of hickory dimension stock in the country. Previous to joining the staff of the *American Machinist,* Mr. Viall was for three years associate editor of *Machinery,* and before that he was for 14 years foreman and superintendent of some of the largest specialty plants in the middle West. He is a member of the American Society for Steel Treating, the American Welding Society, the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Electrical Engineers. He is author of *Gas, Torch and Thermit Welding, Electric Welding, Broaches and Broaching, United States Artillery Ammunition, United States Rifles and Machine Guns, and Manufacture of Artillery Ammunition.* He is especially well known among the machine tool builders of the middle West, particularly Cincinnati.

The Poldi Steel Corp. of America, 115 Broadway, New York, recently has announced the establishment of a new warehouse at 173-175 Spring street, New York City. A large stock of high speed steels, tool steels, alloy steels, special steels, spring steels, machinery steels and drill rods will be carried.

William Printz, sales engineer, who has been actively associated with the sale and installation of pyrometers throughout the middle west for the past five years, has assumed charge of the New York territory for the Wilson-Maeulen Co., New York, manufacturer of pyrometers. His headquarters will be at the main office and works, 383 Concord avenue, New York.

Darwin & Milner, Inc., 11 Waverly Place, New York, announce that effective Jan. 15 the central offices and warehouse of the company were centralized at 403 Long avenue, Cleveland. H. Reinhart, 80 Rutland road, Brooklyn, N. Y., will act as general district agent for New York and adjacent territories while the Brooklyn Steel Treating Corp., 8-10 Franklin street, Brooklyn, N. Y., will be the special representatives for New York city and will also carry some stocks. Other agencies will remain as before.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is free to all members of the Society. If you wish a position, your want ad will be printed free in two issues of the Transactions.

This service is also free to employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published free in two issues of the Transactions.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS OPEN

WANTED—Man to take charge of hardening room in gear manufacturing plant located in large city in Texas. Position permanent to right party. Answer PO-4

POSITION OPEN—for a steel salesman for Illinois and Iowa. Desire man acquainted with trade in Tri-Cities. Man with practical shop and hardening experience preferred. Permanent position to right man with opportunity for advancement. Salary to start $175.00 and bonus. Answer PO-2

POSITION OPEN—Want to get in touch with a few established manufacturers, agents or high calibered district salesmen to sell the best heat resisting alloys obtainable. We are making some changes in an established organization. Answer PO-3

POSITION OPEN—for thoroughly experienced metallurgist to take charge of heat treating department and all its branches, with one of largest manufacturers of farm implements in the country. Answer PO-5

WANTED SUPERINTENDENT—First class pyrometer man, capable of handling installations service work, pyrometer maintenance, and instrument repairs. Answer FO-6

POSITIONS WANTED

WANTED—Position as sales manager, Gentile, of years of experience in tools, tool and alloy steels with unquestionable references in every respect, including many very desirable accounts, thoroughly acquainted with Middle West trade, capable of organizing and handling either main of district office, open to negotitate. Answer 1-33

WANTED—Position as chemist or metallurgist. Seven years experience in carbon and alloy steels. Thoroughly experienced in laboratory research, testing, and shop problems concerning steel. References. Answer 1-34

WANTED—Position as chief or assistant metallurgist. Graduate of University of Michigan. Five years' experience with largest motor car manufacturing companies. Salary $3600.00 Answer 1-5

WANTED—Position as metallurgist. College training. Qualified to direct chemical laboratories. Thoroughly experienced in modern physical test methods, pyrometers, foundry and plant control. A-1 references. Michigan territory desired. Answer 1-6

WANTED—Metallurgical position. College graduate in metallurgy. 26 years old. Has been employed with large steel concern having control of pyrometers. Has also done metallographic work. Answer 1-7

WANTED—Position as metallurgist. Capable of directing heat treating department and chemical laboratory. 8 years' experience in forging and steel stamping field. Answer 1-18

WANTED—Position as metallurgist in New England territory. Married. College graduate. Extensive experience in analysis and testing carbon and alloy steels in automobile and aircraft plants, also industrial research. Salary $60.00 a week. Answer 1-9.

WANTED—Position as foreman of heat treating plant. 37 years old. Married. Valuable experience. Best references. Detroit territory preferred. Answer 1-10

WANTED—Position in vocational shop training or foreman of production department. Graduate of University of Missouri. Extensive experience. A-1 references. Missouri or Illinios locality preferred. Answer 1-11

WANTED—Position as foreman of heat treating department. 5 years' in charge of large automobile company's plant. Best of references. Detroit territory preferred. Answer 1-12

WANTED—Position as metallurgist in Chicago or vicinity. Married. 30 years old. 3 years in Chicago Technical College. 6 years' practical experience. Salary $3000.00. Answer 1-14

POSITION WANTED—As metallurgical engineer in technical or executive capacity. Six years experience in the automotive industry with few well known concerns. Experienced in physical and chemical testing, metallography, design of modern heat treating plants and control. Technical graduate. Married. Age 29. Answer 1-15

WANTED—Position as steel salesman. Has large trade in New England states who are users of high speed as well as carbon steels. Is thoroughly experienced man and capable of making demonstrations. Trade consists of some of largest machine companies in East. Can furnish best references as to ability as salesman and as to character. Answer 1-16

WANTED—Graduate engineer at present employed as assistant to metallurgist in one of largest tractor companies in United States is open for position as assistant metallurgist, heat treating superintendent, supervisor of physical tests, chief chemist. Four years experience. Answer 1-17

WANTED—Position as foreman of heat treating or blacksmith shop. High School graduate. Married. Specialized in heat treating for 10 years. Valuable experience. Best of references. Answer 1-22

WANTED—Position with future. Graduate special course in Carnegie Tech. Locality desired, Detroit or East. Engineer of tests during war. Foreman of tool dressing and tempering department. Excellent references. Answer 1-23

POSITION WANTED—California location desired—as superintendent or foreman of heat-treating department by a steel treater with more than 20 years' experience. Have specialized in carbonizing and the construction of special furnaces for steel treating. Address 11-60.

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